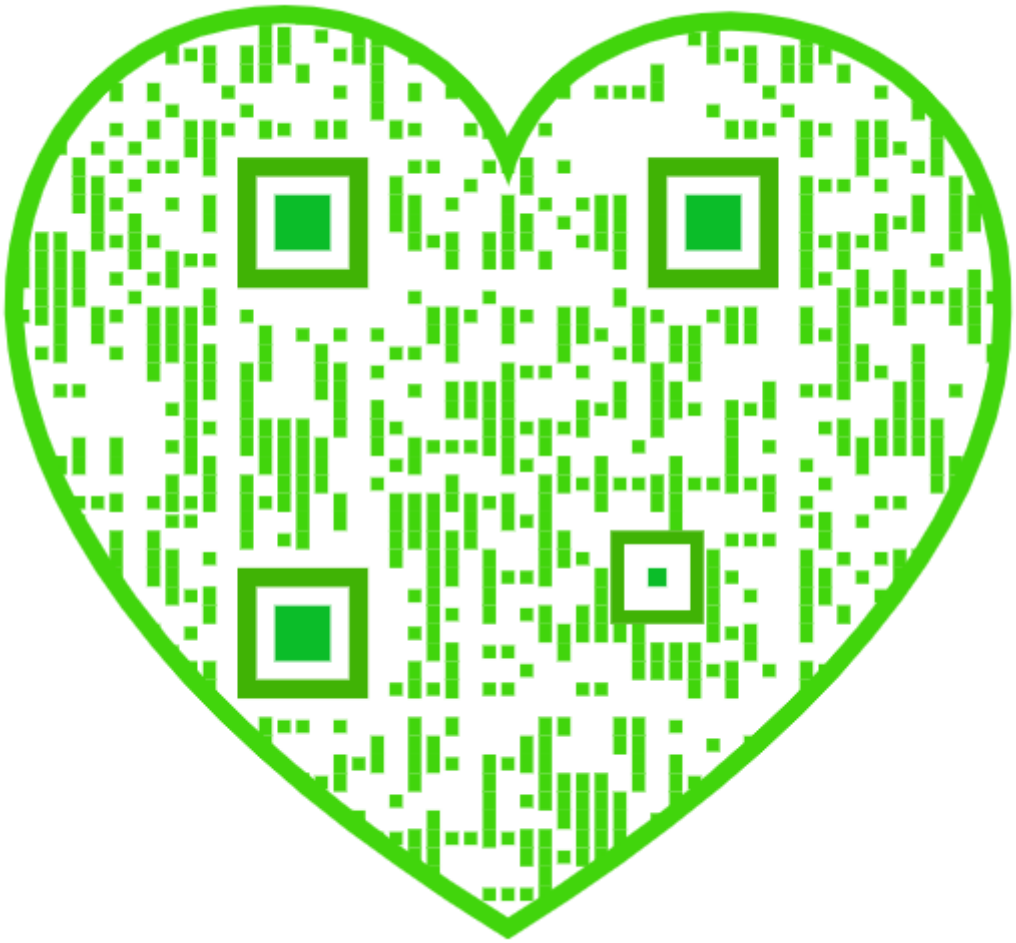
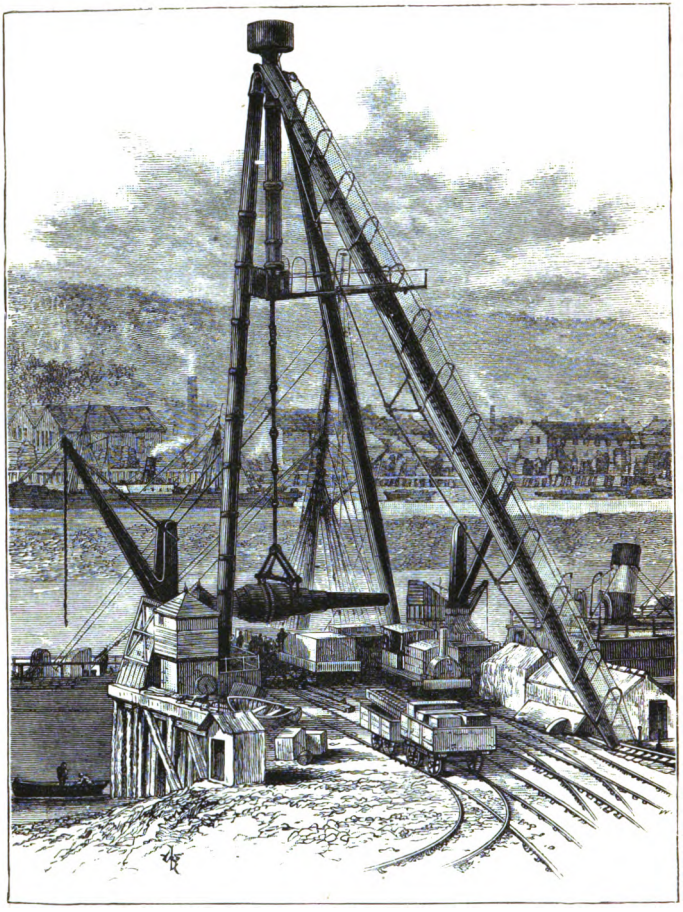
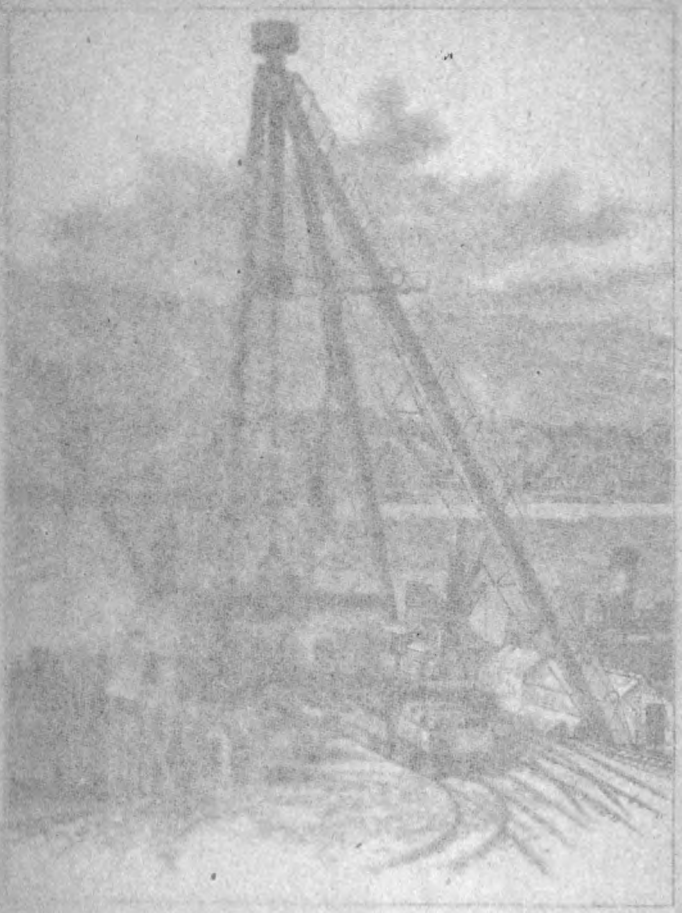




THE GREAT CRANE. A HUNDRED-TON GUN IN MID-AIR.



The Leisure Hour Library—New Series

FOUNDRY, FORGE AND FACTORY

107455

WITH A CHAPTER ON THE

CENTENARY OF THE ROTARY PRESS

BY

W. J. GORDON

AUTHOR OF 'HOW LONDON LIVES,' ETC., ETC.

THE RELIGIOUS TRACT SOCIETY

56 PATERNOSTER ROW, 65 ST. PAUL'S CHURCHYARD

AND 164 PICCADILLY

1890

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PREFACE.

THIS book is the outcome of a trip to the workshops of the North. It takes us from the Tyne to the Forth and Clyde, and back by way of Barrow, Liverpool and St. Helens, to Manchester and Birmingham. It deals with many phases of industry, some of which are new. And it is not a mere refurbishment of old material, but the result of personal observation and inquiry at head-quarters regarding the skilled workman of the day as he is found at work amid the most recent inventions.

In the main it has already appeared in the form of articles in *The Leisure Hour*, which are of recent publication and have been revised to date where any revision was necessary.

By way of preface, the Author begs to tender his thanks to the heads of the great establishments it describes, who gave facilities for the papers being written, and also read the proofs, with a view of ensuring a freedom from exaggeration and error, which, as a rule, is only expected from writers who have spent their lifetime in each of the several trades.

W. J. G.

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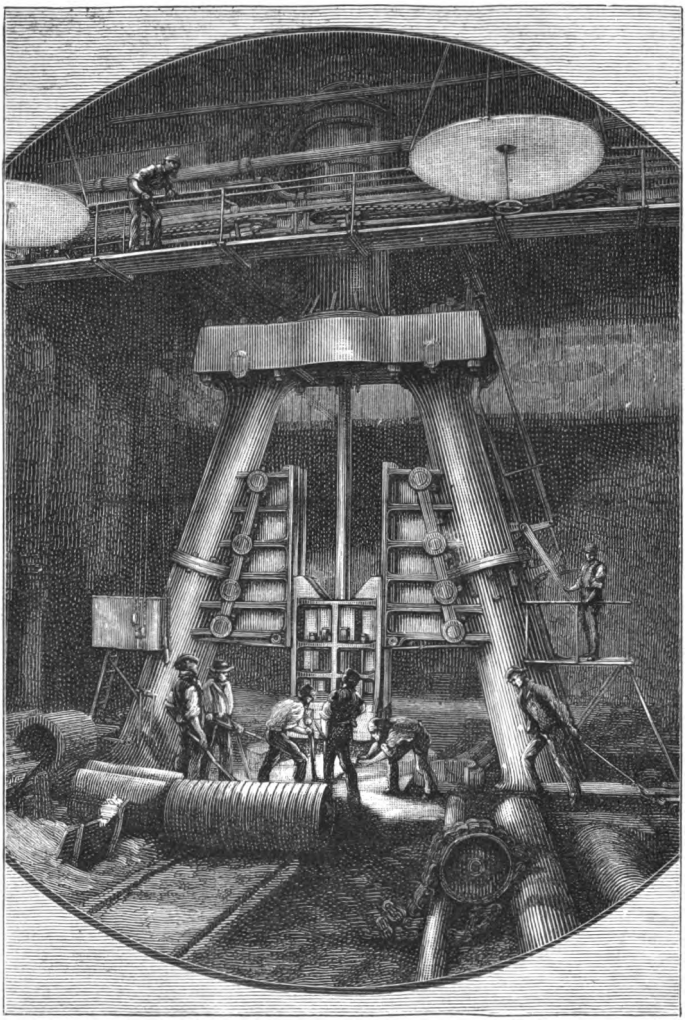


THE GREAT STEAM-HAMMER.

W. G. Armstrong

FOUNDRY, FORGE, AND FACTORY.

CHAPTER I.

'ARMSTRONG'S.'

ON a fine day the busy, coaly Tyne is a pleasant river; but on a wet one, with an easterly wind, it is seen at its best—that is to say, under an aspect which no other stream can yield. And it was at its best that we saw it when we last approached Newcastle.

The furious wind came driving in from the eastward, and the bitter rain slanted through it, bringing down the soot and impurities in flakes from the dense clouds above.

Low in the air hung the smoke as it rolled to the west over the city. Earth, air, and water, all were carboniferous. Coal is cheap on the Tyne, and so are chemicals. Smoke there was of all varieties, ranging from unmistakable black through a gamut of greys to fleecy white; hundreds of chimneys there were of all heights, pouring forth their voluntary contributions, to be swept and cleansed by the torrential rain which pattered on the deck in impetuous drops. As we followed up the narrow windings, towers and chimneys would appear and disappear, their vertical lines cut into disjointed segments by the fumes from neighbouring stacks thinning off on their way to the west. Here and there in the darkness a gleam of fire would peep from some forge or furnace-hole above the wall of waste heaps forming the river bank. The ships in the stream, moored in twos and threes, stood out cheerlessly against the foggy background. Hulls in frame, hulls ready for launching, hulls just launched, would show their fair and bulky proportions as the gusts for a minute lifted the driving fog. A bird or two, looking quite white by contrast, would come sailing along and lightly drop to the surface of the water in search of a morsel of food; and out of the darkness ahead of us would loom the clinker-built tugs and broad-beamed lighters on their seaward way. A squall clears the cloud a little, and we see a wire railway to the left, or rather—for the wires are invisible—the trucks go floating through the air like rectangular balloons. Then the curtain drops again, and then comes another gust, another rift in the pall, and there in front of us is the swing-bridge and the high-level, and we are at the pier. Up through the cruel rain we go, past the old church, now the cathedral, of St. Nicholas, past the railway-station, and down the road to Elswick.

Elswick is the pride of Newcastle; and Newcastle is now of considerably more importance than when Hadrian built the Pons Ælii over the Tyne and planted the garrison at its foot to defend the wall which was then the Roman border. The great arsenal of the North has no rival in Britain. Krupp's works at Essen are the largest on the continent of Europe, and yet the Essen works do not include shipbuilding.

In the admirably situated establishment on the Tyne peace and war go hand in hand, and side by side there spring into being the mighty war-ship and the peaceful penny boat, the ships that bring us our food, the machinery that receives and stores it, and the guns and cruisers that we are forced to build for its protection.

In rendering an account of these famous works, which employ 10,000 men, cover more than fifty acres, and run for more than a mile between the river and the railway, let us begin with the ore and end with the ironclad, following the engineering, the guns, and the ships through their several stages. Our first care, then, is the raw material—a huge pile of Spanish hæmatite stretching along the railway like an embankment, and worked by the men as if it were a mine. In front are a few truck-loads of pig-iron brought from the blast-furnaces that stand near the hammer-shed, where the mighty thirty-five-tonner is shaking the earth with its curiously deliberate beat.

The three furnaces rise boldly from their foreground of sand, over which the water-jets are playing. Around the three towers, eighty-five feet above us, there runs the balcony from which the fires are fed; and the cages of the hoist laden with ore and fuel are rising with instalments of the meal. Two barrow-loads of ore, then two barrow-loads of coke, then two barrow-loads of lime, then two barrow-loads of ore, then two barrow-loads of coke, and then two barrow-loads of lime—twelve barrow-loads altogether—are thrown on the conical furnace-lid, and then the weight becomes too much for the lever, and down slips the mouthful into the gullet of fire.

A quarter of a mile to the east of us, past the ore bank, are the steel-works, a somewhat recent addition, with their sheds arranged in terraces up the slope of the ground. Here are the half-dozen producers, to give the gas for the two Siemens's furnaces, which can, if pressed, turn out their four hundred tons of ingot steel per week. The gas goes by brick flues to the back of the furnace, and there, entering and mixing with the air, bursts into flame and begins its ardent work. The waste heat warms up to redness the chambers through which it passes off, and into these

red-hot chambers the fresh gas and air are turned and heated before they enter the melting-chamber. Nine tons and more of mild scrap steel, and over a dozen tons of pig-iron with three tons of ore, have gone to form the fluid now in the furnace, and as a few of the fist-like lumps of ore are scattered in, we see them thrown up and danced on the glowing surface like a shower of meteors. To test the mixture, a spoonful is occasionally taken, much as a cook samples the broth as it boils; but the large ladle by which the charge is carried is six feet across and five feet deep, and holds a score of tons.

From the steel furnaces our attention is directed to the peaceful engineering-sheds, where the shears that form one of the landmarks of the Tyne were made. And here are other cranes of the same species—*Grus elswickiensis*, ironically speaking—in various stages of development. Here are some of the limbs of a specimen which, when complete, will stand ninety-six feet high, weigh 700 tons, and lift 160 tons. Like the rest of these hydraulic cranes, it is to be direct-acting, with the cylinder in the air and the piston-rod taking the place of the chain, which is so frequent a source of danger. Here are some cranes being made which are to lift laden trucks from a low-level railway to a shoot thirty feet above, into which they are to be tipped so as to send the ten tons of coal they contain down into the ship's bunkers, and these are to be workable at such a rate as to lift and shoot by each hoist 400 tons per hour.

A great deal of dock machinery is in hand. Around us machines of almost every class are seen in almost every stage—whips and jibs, and pumps and jiggers, hoists and lifts, and traversers and winders, and even lighthouses; and of course bridges, fixed, draw, and swing. For moveable bridges Elswick has a world-wide reputation, and of the two classes, draw and swing, there are no better examples in existence than its 400-ton drawbridge at the Kettendyk Basin at Antwerp, and the 1,400-ton swing-bridge between Newcastle and Gateshead, which has taken the place of the old arched structure at the foot of Stephenson's high-level.

All these bridges are moved by hydraulic power, and,

indeed, it was for the making of hydraulic machinery that the Armstrong works first came into existence in 1847. 'Armstrong's' is the familiar yet significant name by which they are known in all the country side. It is an old story now how the Newcastle solicitor became an engineer; how, in 1836, Lord Armstrong, when travelling through the Craven vales, noticed the 'mountain rills, which, descending the steep slopes of the hills, expended their energy in the production of streaks of foam, thereby adding to the beauty of the landscape, but fulfilling no purpose of utility,' and how he was thus led to invent and gave the world the hydro-electric machine, the hydraulic crane, and the accumulator. It is familiar to all of us how he invented the gun that bears his name, and, presenting his patents to the Government in 1858, became for some time the head of Woolwich Arsenal, introducing into our service in three years over 3,000 guns of from six to 600 pounders; and how, in 1863, the year he was President of the British Association, he rejoined Elswick, which has now, with the Walker shipyard, become the property of Armstrong, Mitchell, and Co., Limited, with a share and debenture capital of over two millions.

And now let us enter the foundry, a gloomy, sultry hall, some ninety yards long by seventy wide, doing duty for the cave beneath Mount Etna. Here the modern Vulcans, in shirt-sleeves and with unbroken legs, are still casting thunderbolts, though not those of Jove, and instead of being helped by the two golden statues of their own make, are assisted by the eight long travelling cranes from the engineering-shops we have left.

The floor is covered with 'moulds.' Here is a 'pattern' come in from the pattern-shop, and laid on the flat 'turn-over board.' On it the bottom half of the moulding-box is laid and filled with sand, which seems to be nothing but well-pressed loam. Then it is turned over and the sand swept off the face smoothly down to the edge of the box. The parting sand—burnt loam, in fact—is scattered over the face, the top of the moulding-box is put on and filled in as the bottom has been, and a small piece of wood—the 'git'—is thrust in to leave the hole by which the metal is

to enter. Then the top is lifted off, and, thanks to the parting sand, comes away easily without disturbing the contents of the bottom box. Carefully is the pattern taken out, and the two halves of the box again brought together; and then the crane brings the metal in the cauldron, and we see it poured into the mould.

Around us castings of all sorts are in progress, and from the boxes into which the molten metal has been poured leap spiteful little jets of flame as slowly, very slowly, it cools. Some of the men are busily moulding. One is sifting or 'riddling' the old sand to make it ready for another casting. Others are carrying small ladlefuls of glowing metal and pouring them in for shells.

When shells are cast and it is necessary to chill the points, the moulds have a metal end. Metal being a better conductor than sand, the heat escapes more quickly through it, and the molecules, being more rapidly cooled, form a hardened rigid mass. These shells are of all sizes, from seventeen inches in diameter downwards, the smallest weighing but three pounds, and the largest about a ton! Just over the way is the shell-shop, where they are taken in and finished, and stand arranged in groups like brightly-painted sugar-loaves in a well-lighted grocery store.

As we again pass the blast-furnaces—which we are told can turn out in full work over 87,000 tons of pig per year—we look in at the beam-engine with its weigh-bar gearing, which has steam cylinders a yard in diameter, blast cylinders of eight feet, and a fly-wheel of twenty-five feet. To feed this giant—which drives the blast through eleven stoves while it is being heated up to 1,450 degrees Fahrenheit—there are ten seventy-five feet boilers, and as each of these holds 3,360 gallons, the ten together require 150 tons of water to fill them. They are, of course, heated by the gas which come off the furnaces, and which is brought to them in pipes almost as large as those in which the blast is carried. In the good old days the country was alight from the flames that poured out of our blast-furnaces, but in this age of steel we know better, and all the wild blaze is economized.

We enter the hammer-shed, where the huge thirty-five-

tonner is doing its thirty-six strokes per minute on an ingot that is being swiftly forged into the shape of a gun. At every thud the ground shakes, and a deep dent is made in the mass, which began by being cylindrical, was then beaten into a square, and is now having the angles of the square knocked in so as to form an octagon. The ingot is hanging on the hydraulic crane which brought it from the fire, and it is being moved and manipulated by the men, who with long capstan-bars thrust into the hooks of a many-branched carrier affixed to its end, seem to twist it and turn it as they please. At every blow the lump is flattened in as if it were a stick of liquorice. The dull red of the mass flushes up vividly as the blow is delivered, and the brightness of the glow throws the surroundings into gloom. We are in front of the hammer, the men are behind and above us, and at each angry flush of the glowing bar a little lad leaps forward with a broom and sweeps the anvil free of scale. Leisurely and cruelly the blows follow in regular succession. When the high-level bridge was building close by, the hammers were kept going on the piles, striking sixty and seventy strokes a minute, and the pile-heads were frequently aflame with the percussion; but the steam-hammers of those days were but pigmies to this, and their fussy little slaps were but flea-bites compared to the deliberate belabourings of this monster among machine tools. The steam lifts it up and the steam drives it down, and the power of the steam added to the weight of the head gives a blow that is tremendous; the wonder is that the walls of the shed are not shaken to pieces as they jolt at the shock.

Having seen the forging, we go to the boring-shop. On our way we notice eight men staggering under a piece of railroad iron, and here are masses to which that rail is but as a straw to a gate-post, slowly and resistlessly revolving as if they were struggling in vain to keep still. Here is a cumbrous cylinder over forty feet long, destined in time to become one of the 110-ton guns. A piece has already been cut off its end to be tested—and before it is completed the number of tests the gun will have to undergo will amount to 368! To finish such a gun at least fifteen months are

required, working night and day. There will be five thicknesses—a barrel of five inches, a second course with the shaped muzzle of six and a half inches, a third course of three and a half inches, a fourth course of four inches, and a fifth course of six inches, giving a total thickness of over two feet. The powder-chamber will be twenty-one inches in diameter and seven feet long, and hold a charge of 900 lb., and it is calculated that it will drive a 2,000 lb. shell with a velocity of 2,000 feet per second, the energy being equal to 56,500 foot-tons! The comparison of guns is now based on energy, and extreme range is disregarded; but it is worth noting that this gun will have a range of about fourteen miles, and will be able to shoot clean over London and bombard Hampstead Heath from Woolwich Common.

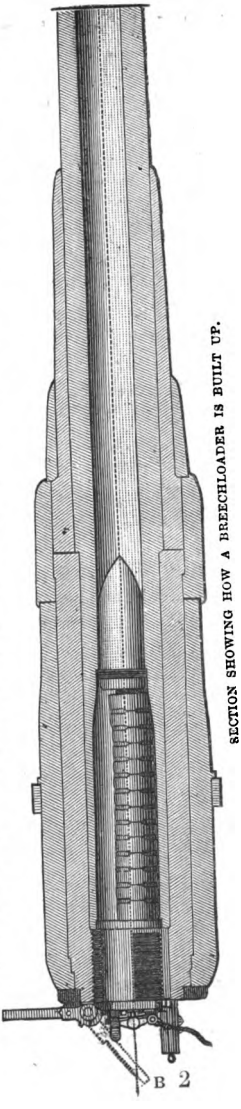
Most of the world's ordnance is now 'built up' on the principle invented by Lord Armstrong. When the gun was a homogeneous mass the strain of the firing was practically borne by the parts immediately close to the bore, and the thickness of the metal gave but little additional strength. Now each layer of the gun is in a state of tension to begin with, and this has to be overcome before the normal resistance of the metal comes into play. First there is a steel tube, carefully turned; on to this tube is slipped a ring or coil, which when cool is too small to pass over it, but which when heated expands, and is slipped into position, gripping the tube with tremendous force as it cools. Over this coil another heated coil is slipped in similar fashion, and ring after ring is added until the gun is complete. The ring fits on as the tyre fits on a wheel, the shrinkage giving the requisite strength.

Formerly guns were made of compositions known as gun-metals; now steel can be made having all the needful toughness and elasticity. The ingot, as we have seen, is cast and forged, and then it comes here. At first it is rough bored, should it not have been cast hollow. To bore it is a long job, continuing night and day from Monday morning to Saturday afternoon, and takes, even in the case of a thirty-feet barrel, more than a week. It is a work of exceeding care, for the slightest deviation in any direction would spoil the ingot.

After the rough boring the tube is taken on the crane to the oil-pit to be tempered by being raised to a red heat and dipped; and it then comes back for the fine boring. In our 110-ton gun this will occupy three months, during which time the cutters pass up the tube three or four times, each pass taking two or three weeks, each paring away a thinner shaving than the last, until in the final pass perhaps only the five-hundredth of an inch will be removed.

The next process is turning the outside to receive the coils, and this is now going on with the gun in front of us, the bright steel shavings curling off like lengthy paper spills, looking so innocent, and being really so hot that our hands cannot hold them. As the huge lathe goes slowly round—and some of the lathes have twenty-feet chucks and sixty-feet beds—the cutter seems to strip the shavings off as easily as a finger-nail would gouge them out from a cylinder of soap, and the rest seems to travel up the slide no faster than the hour-hand of a clock.

The turning being ended, the barrel is ready for the hoops, which are forged in the hoop-shop at the other end of the factory. The hoop is taken to one of the twenty-five-feet drilling machines. Its inside is cut out to be just a little smaller than the barrel. It is then taken back to the forge and re-



SECTION SHOWING HOW A BREECHLOADER IS BUILT UP.

heated by gas to a less than red heat, and it is then slipped over the barrel, while cold water is run through the bore to keep all cool. When this is done the gun is upright in a pit, the rings being dropped on to it by the crane.

The gun is now built up and ready for rifling. A 110-tonner will take a month on the rifling machine. A drum the size of the bore is thrust down it. At the end of the drum is a tooth-like cutter, which can be set at any pitch, and as it comes back out of the gun it cuts a groove, which it has to traverse again and again until it is of the requisite depth and width. Were there no other arrangements the groove would be straight, but by means of the sloping bar a rack is worked against a pinion, the pinion receives its twist, and the drum, gradually turning as it retires, gives the spiral curve of the rifling. As the slope of the guide is constant the curve is constant, and the pitch of the rifling can be altered at will by the pitch of the bar. Over each groove the cutter has to travel perhaps a dozen times, and, as there are eighty grooves to finish, the cutter may have to make over 900 journeys, at every journey taking off from a fiftieth to a twenty-fifth of an inch. Were the cutter to go wrong, the fourteen miles it may have had to travel up and down the bore would have been travelled in vain, the gun would be spoiled, and £15,000 of work and material thrown away.

We are next initiated into the construction of the breech. We admire the ingenuity of the interrupted screw, and are shown its action. The breech-piece is a mass of steel, with a screw-thread which, instead of running right round, is broken with four smooth intervals. The screw in the gun is similarly interrupted with four smooth intervals in quarter sections, which thus occupy altogether half the circumference. The breech is closed with a hinge, and as the thread of the breech alternates with the thread of the gun, it shuts direct, and when it is in position a quarter turn of the lever locks the threads into each other, tightening all up, and giving the bite and strength of a screw of half the length. The screw runs the full length of the breech-plug, and this is considerable. In a 110-ton gun

the breech-plug is thirty inches long. In the Krupp guns the breech-piece is not hinged, but consists of a ponderous wedge, which has to be withdrawn by main force.

To prevent the escape of powder gas an elastic steel cap is fitted on the front of the breech-screw. The back of this cap is flat, but the front of the screw is slightly dome-shaped, so that the cap only bears against the face of the screw at the centre. When the gun is fired the pressure of the gas bends the cap back over the face of the screw, forcing the flange of the cap close up against the tube, and rendering escape impossible. The firing arrangement, with its levers, all of which must be in position before the hammer can strike the primer, is another triumph of ingenuity; and at last, after seeing how the gun is not fired, we have everything in position, with the breech safely locked, and with a pull of the lanyard the hammer strikes the primer and off it goes. The primer is a cartridge in a close-ended tube of flexible metal, and it is fired without any hole being made in its base. In the large turret-guns the primer is fired by electricity, entirely under command of the officer on duty. In the 110-ton gun hydraulic machinery is used to turn the breech and load the gun.

When the guns are rifled, cleaned, and completed, an impression in gutta-percha is taken of their insides, and they are taken away to be proved, unless they are for our own Government. One of the trial ranges is at Ridsdale, thirty-five miles away to the north-west; the machine guns are tried near Rothbury; and the big guns go to the tidal range near Silloth, on the western coast.

There is one gun being made at Elswick which is not on the coil principle. This is 'the riband gun,' on which principle the armament of the Esmeralda was constructed. First comes the long steel tube as on the other system, and then this, instead of being clasped by steel hoops, is wrapped round and round by a riband of steel. The riband is about an eighth of an inch thick and a quarter of an inch broad, and is wound on cold from a drum. There is heavy brake power on the drum, and the steel strip is wound off in a state of high tension. The strain is varied with each layer, and in a ten-inch gun there are fourteen

layers. This 'wire gun' was thought out thirty years ago, but it is only within the last six years that the notion has taken practical shape. If, however, all we hear about it is true, the ordnance of the future will have to shuffle off its mortal coil and assume the spiral, in which, according to Goethe, civilization has ever advanced.

But let us descend from guns in general to guns in particular. We may as well begin with the one nearest to us, the smallest, as it happens. It is a seven-pound screw gun for mountain warfare, and is seven feet long, with a bore of two inches and a half, sending its projectile from three to four thousand yards. The gun itself weighs 400 pounds, and, with its carriage, ammunition, and gear, is carried by six mules. The first mule takes the muzzle part, which is fitted into a leather cup at the screw end to protect it from damage; the second mule takes the breech part, which has also its cup, the screw end in this case being carried pointing to the rear, while that of the muzzle points to the front; the third mule takes the axle and the fittings; the fourth mule carries the wheels of the gun, one on each side; the fifth mule carries the trail of the carriage; and the sixth mule carries the ammunition. It thus takes two mules to carry the gun and three to take the carriage; and thus dividing the weight, it has been possible to get artillery up valleys and into positions in Afghanistan and elsewhere where the ordinary fixed-wheelers could not go. A strange-looking affair is the gun and its carriage when in sections, but when the sections are all screwed up into their proper places, and we see the mule gun ready for action, we find that it is really an elegant weapon, showing but little trace of its peculiar style of travelling. The time required to unload and piece the gun and carriage together ready for action is under one minute.

Here is the new twelve-pounder, which is now being issued to our Horse Artillery. It weighs seven hundredweight, is seven feet eight inches long, and has a three-inch bore, taking a four-pound powder charge, projecting a twelve and a half pound shell at the rate of 1,800 feet per second. The carriage has an elastic spring arrangement by which the recoil is eased off, but this, with the means of

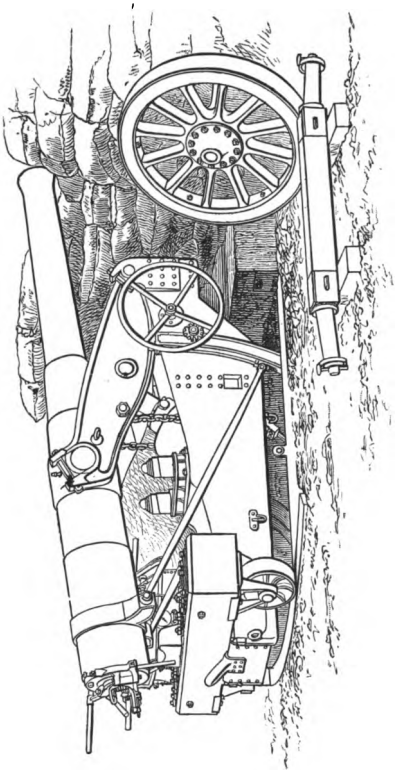
sighting and working the gun, can hardly be described without a technical drawing. The bore of this gun is three inches, but the powder-chamber is 3·625 inches, and is eleven inches long. In all breechloaders it may be as well to note the powder-chamber is larger than the bore of the gun. In a forty-three-ton gun, for instance, it exceeds the bore by four inches.

In this finishing-shop the guns are polished, browned, and varnished, and guns of all sizes are round us in various stages of completion. Close to us is a sturdy howitzer—a howitzer, it may perhaps be as well to say, being a short gun with a large bore, throwing large shell at high angles, and taking the place of the almost obsolete mortar. Over yonder is a great thirty-tonner, with a bore as big as a man's head. Here is a little Gatling, and away there half a dozen mountain guns, all bright, clean, and smart. No very large guns are in the shop, for they have to be finished where they are made.

In the carriage-shops we are in a new world of ingenuity. Here is a six-inch gun on a Vavasseur carriage, in which the recoil is all exhausted in a few inches. What a contrast to the old wheeled carriages, with their long backward run checked by the breech-ropes in the vessel's side! In this compact contrivance the hydraulic resistance is gradually increased, so as to bring the gun to rest as quietly as on a cushion. When the gun is fired the cylinder is full of water and the valve wide open, but as it recoils the valve, worked by a spiral movement, is gradually shut off, and, as the exit lessens, the resistance of the water increases, and at last entirely absorbs the force of the backward thrust. This six-inch gun is stopped dead in eighteen inches. It is curious with what ease these large guns are aimed and elevated. A slight turn of the handle brings the piece round or up or down as quickly as if it were being held at the shoulder, and so true is the gearing that the required position can be obtained as accurately as if we were working with the fine adjustment of a microscope.

In the centre of the shop is a gun mounted on the new Elswick hydro-pneumatic disappearing carriage. The idea

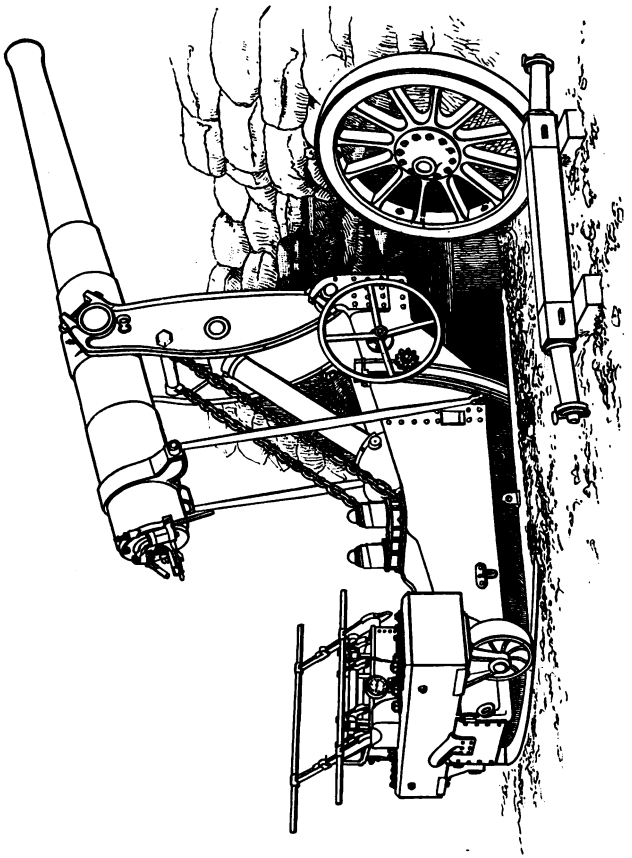
of the gun, as it stands, is that it should be sunk in a pit, say on one of our chalk downs near the sea. The flat shield would then act as the roof of the pit, and the gun



THE ELSWICK DISAPPEARING CARRIAGE—LOADING POSITION.

when loaded would rise through the space that is left for it, and be aimed either by the man going up in the usual way, or by means of the two mirrors, which show below what is going on above and outside. The gun being fired,

the recoil brings it down into the pit to be loaded. As it sinks it works a piston, which, driven into a cylinder, sends



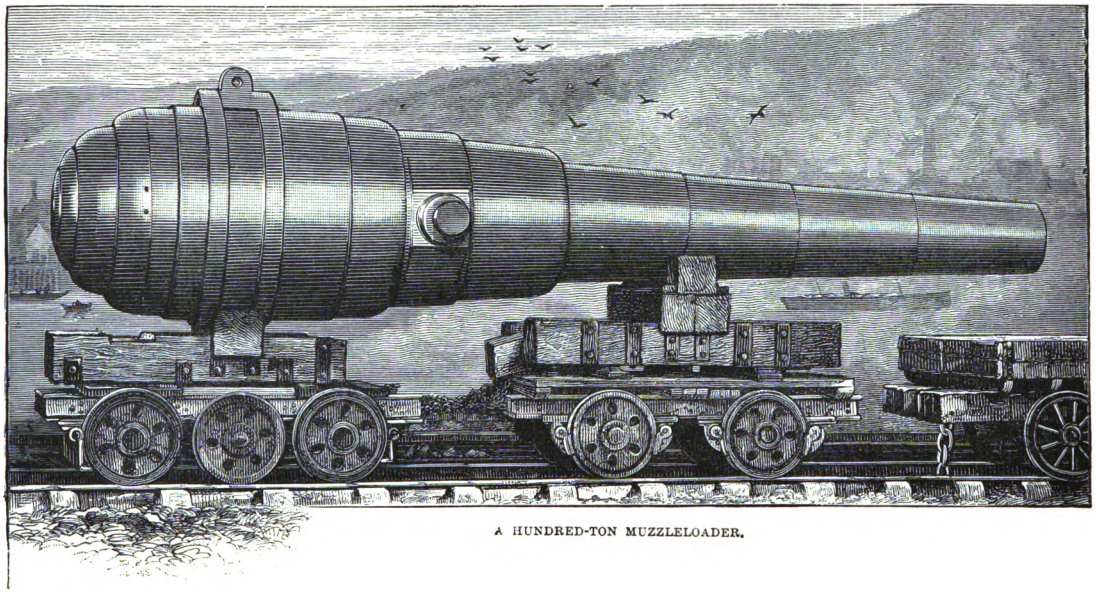
THE ELSWICK DISAPPEARING CARRIAGE—FIRING POSITION.

the water it contains into another cylinder containing air. The air is compressed, and the force thus stored up is that

which, when the gun is loaded, raises it up again to fire. No expensive armour plates or fortifications would be required with this carriage. The gun would remain in sight only long enough to fire. The enemy at sea would sweep the chalk hill in vain for a sign of its presence other than the smoke; and should he be fortunate enough to hit on the exact position, he would not only have to get the direction, but he would require to have the range so truly as to drop his shell into the hole through which the gun appears.

The carriage and its fittings weigh almost twice as much as the gun itself. A 110-ton gun complete weighs 300 tons. At the other end of this shop we come upon a carriage for a monster, nearly finished. One of the strangest of the very latest developments of modern gunnery is the abolition of the trunnions. The gun has abandoned its arms for grooves. This has been necessitated by the desire to reduce as far as possible the size of the opening in the turret armour through which the gun fires. At first sight a trunnionless gun has a curious crippled look about it, though its limbs have been shrinking for so many years that their total disappearance is not to be wondered at.

As we have returned to our guns, we may as well say something here about the machine guns, which have hitherto adroitly slipped out of our notes as we came across them. The largest of these is the Elswick machine cannon, which takes a six-pound shell. This gun is worked on a pillar, and is easily recognizable by its curious leather-covered shoulder-piece, by which it is manipulated. To work it three men are required. One works this shoulder-piece, and by it aims the gun; another puts in the full cartridges and catches the empty ones, and another opens the breech and fires. As the handle is lowered the breech is closed and the gun is cocked; as the handle is lifted the empty cartridge-case is thrust from the gun. The breech-block is linked to the body and mounted on a non-recoil carriage, whose two recoil cylinders prevent it in any way interfering with the men. This gun, which has a bore of two and a half inches, can fire from ten to fifteen shots per minute,



A HUNDRED-TON MUZZLELOADER.

and is specially designed for use against torpedo-boats, as it can be swung about in every direction.

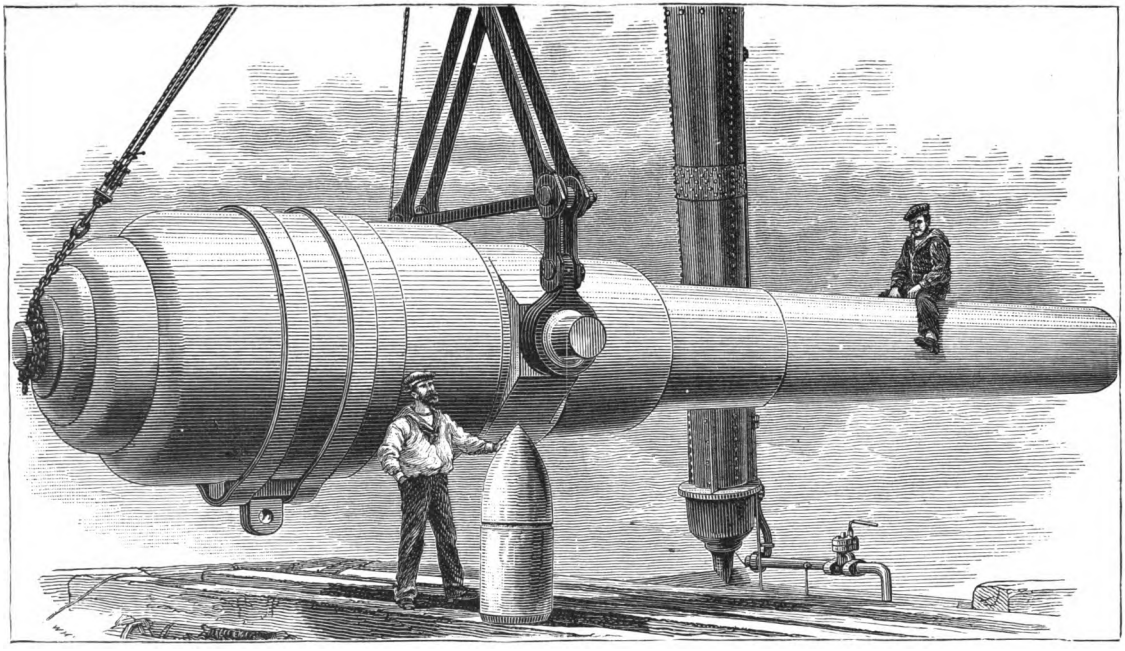
The Gatling gun is a much lighter affair. It consists of ten rifle barrels, grouped like a lictor's fasces round a central spindle and covered with a cylindrical tube, simply for appearance' sake, to make it look more like a gun. To the breech is fixed a drum with 104 bullets, and these are thrust forward, fired, and the empty cartridges withdrawn by highly ingenious mechanism, the time required to fire a drum-full being two and a half seconds. The barrels are the same bore as those of the Martini rifle, and the gun, with its automatic Accles feed, can discharge its 1,200 shots a minute at any angle of elevation and depression, and even immediately beneath its stand.

Elswick is the English manufactory of the Gatling as well as of the Hotchkiss guns and shells, which we saw being made in such numbers in the shell-room, to which for a minute we may as well return. These Hotchkiss shells we see from their coming rough from the mould up to their brass ring being polished on the lathe. Every shell has a threefold ring of soft metal just a little larger than itself. The shell fits the bore of the gun exactly; the brass, being larger, is squeezed into the grooves, takes the rifling, and gives the twist. The shell being put in point foremost through the breech, the charge is put in behind it in the powder-chamber, and when the explosion takes place the ring squeezed into the grooves takes the place of the old studs that used to work such havoc with the guns. Shells are around us of all varieties. Common shells, shrapnel, Palliser, chilled steel, and case-shot. Now that steel is used instead of iron the shell-wall is much thinner and the death-dealing contents more abundant than of old. Now a six-inch shell holds twelve pounds of powder; in the iron age it held seven pounds. One of the most interesting shells is the shrapnel, which runs up to 1,700 pounds in weight. The whole of the inside of the shell is filled with ounce bullets, and melted rosin is then poured in to fill up the interstices and save the leaden spheres from being shocked into jam by the explosion. As we peep into the mass looking like marbles set in glue, our thoughts are carried

back to the days of the old Victory, when, as she came round the stern of the Bucentaure, she let fly into her cabin-windows a sixty-eight-pounder carronade, 'loaded with one round shot and a keg containing 500 musket-balls.' In those days such wholesale practice could only take place at short range, while now our six-inch guns send their shrapnel, containing 916 bullets, as many miles as the carronades did furlongs, and they are burst at the required moment by means of an ingenious time-fuse. On the other shells we need not linger. All hollow shells are carefully smoothed and lacquered inside, for were the surface to be left rough the friction would probably fire the powder. Hard at the point and tough in the body, the shells for penetrating armour have to be forged and bored and tempered, and then filled with just enough powder to ensure their bursting after they have passed into the ship.

Talking so glibly of making these shells might lead an outsider to imagine that it was a very simple matter, and that the machinery required was nothing very great. What the future may have in store for us in such matters we know not. There is probably coming a time when the molten metal will be poured in at one end of a machine and the varnished shell appear at the other; but at present the processes through which each has to pass are many, and the lathes seem to be innumerable.

What the Elswick stock of tools is worth we cannot say, but there are over 800 machines in the ordnance works alone. There are nine steam-hammers besides our gigantic friend, and there is a band-saw an inch and three-quarters wide which cuts through iron like cheese—strong cheese—though it makes a painful fuss about it. Besides the steam cranes and hydraulic cranes that do the work in the shops, there are seven cranes at the jetties for putting the guns on shipboard; and there are the lofty 100-ton shears which form one of the features of the river. There are large stationary steam-engines—one has a driving-band a yard across, and is at work in a house that is absolutely spotlessly clean; and there are seven locomotives dragging guns and ingots about the yard. There are many



HOISTING A HUNDRED-TON GUN (OLD PATTERN).

forty-feet boring machines and long rifling machines. There are planing machines twenty-one feet by eight feet six inches, and several twenty feet by eight feet. In one of the shops we passed a plane with uprights ten feet apart and twenty feet high; and in another shop there were pointed out five new lathes sixty feet long with forty and forty-two-inch centres, which cost £12,000.

Amongst all this machinery there is of course much risk of accident, and in some of the shops we came across little boards attached to every pillar with 'danger bell' in red letters inscribed thereon. Above each board is a wire which runs to a bell in the engine-room, so that in case of danger or disaster the engine can be instantly stopped. Among nearly 10,000 men hardly a day passes without some one having his arm crushed, his hand nipped, or his leg broken; and though everything is done that can be done for the prevention of accidents, carelessness will assert itself and claim its average of victims. To provide against these accidents an 'Accident Compensation Fund' exists, whose latest report shows the injuries only reach 7·4 per cent. per year of the men engaged. From this report we find that out of 316 cases occurring during the twelvemonth the percentage of danger, &c. —the &c. being the personal equation—is as follows: engine-work, 8·0; outside erectors, 16·5; ordnance, 6·1; foundry, 7·9; blast-furnace, 22·4; steel-works, 18·0; from which here, as elsewhere, it will be noticed that those amongst the guns are safest. The income of this fund exceeds £2,000, and is derived from the workmen, who subscribe every week in proportion to their wages, and from the masters, who each week add to the fund double the amount subscribed by those they employ. In connection with the fund ambulance classes have been established, and of the seventy-eight who last presented themselves for examination, seventy-two passed successfully, thus giving a percentage of ninety-two against the All England rate of sixty-six. No statement would convey an idea of the importance of the injuries for which compensation is granted, for there is only one injury whose gravity is not left to the imagination, and that is death; but the

lowest amount paid seems to have been 2*s.* 3*d.* for a bruised knee, while the highest was £150, the total of the allowances amounting to £1,500.

As we pass out through the shops we notice the little boards hanging about on which each man registers his time, and the work on which he has been engaged. The day-shift men begin in the morning at six; many of them arriving earlier, however, to read the newspapers, for nearly every shop has its newspaper club. To this the subscription is a penny a week, which, as the numbers run into hundreds, allows of a large selection of literature. Every night the daily papers are given away, and the weeklies or monthlies lent out; and every three months there is a sale by auction of these higher-class periodicals, the successful bidder buying the second-hand right for the next quarter, and taking the old numbers as the new ones come in. At six o'clock the bell rings and the whistles in the shops sound, and business commences. As the men come in past the time-office they take their piece or time-boards from the rack, where each is placed against its proper number. These time-boards are kept hung up on the work throughout the day, and about a quarter to five at night the men chalk on them how they have been employed, and the foreman goes round the shop and signs the record, which, as the men leave, is thrown into the time-office box. The statements on the boards are entered into the time-books, and as the week is reckoned from Thursday to Wednesday night, there is no difficulty in working out the wages-list ready for Saturday. At one o'clock on that day the men receive their wages at the time-office. For every time-board thrown in during the week there is a tin box with a similar number, and as the men pass by in rotation each receives the tin box with his pay. As the men arrive in the morning they leave their cans of coffee on a tray, and at half-past six the cans are taken to the cookhouse and warmed for breakfast, which comes at eight. In half an hour the bell goes again, and at eleven a labourer takes round a tray and collects the men's dinners for those who dine in the shop.

Having fairly settled the shells for the present, we enter the shipyard. A busy scene it is, and a noisy one; and in

truth the restless activity of the shipbuilders is far more exhilarating than the wearying creep of the resistless lathes. In the yard are seven slips; and parallel with the river bank, and a few yards off, fronting the slips, are the shops, so that the arrangements are as handy as can be. Much of the land on which the yard is built has been reclaimed from the river, and the pile-driving has been great. The angle smiths are placed on an embankment formed from the deposits of the island of the Meadows, which has figured in the description of so many North-country boat-races, and which is now being cleared away to improve the navigation of above-bridge Tyne.

Off the jetty there is now being refitted a Chilian cruiser, after twelve years' service; but the prominent object as we enter the yard is a new Austrian torpedo-vessel, almost ready for launching. Next to the Austrian is an improved Scout, and if her engine-power is only sufficient to do justice to her lines, the Scout will have considerable difficulty in holding her own against her.

The next, in frame up to her armour-shelf, is an iron-clad of 10,000 tons, building for Her Majesty's Navy. Only three months ago were the orders received from Whitehall, and here she is sufficiently advanced to show her immersed body. As we look down from the slope into the wide basket of steel, round which the men cluster like particularly busy bees, we cannot help wondering how so complicated a skeleton could be shaped and fixed in the thirteen weeks. Below, on the ground, the men are cleaning up the casting of her ram, which has just been brought here from the steel foundry. It is of a size we should marvel at were not our eyes by this time become indifferent to the gigantic, and were not the formidable slab so dwarfed by the reversed arch of the towering hull. As we take our final look at the interior the girders with their span and number make the ironclad in her present state resemble the long roof of a railway-station laid on its back; and there is brought home to us, as was never brought home before, the derivation of the cathedral 'nave' from 'navis,' the ship—turned keel upwards.

As vessels are launched stern foremost on the ways made

out into the river—the builder's framework being knocked away all but the central cradle, which falls to pieces as it floats—the hulls in process of construction have their bows away from the bank. And uncouth monsters they look in their early stages of development, as they here seem to have crept up out of the stream on their way to the line of shops to watch over the fitting of their future vestments, on which the drillers and rymers—those 'aitchless bards of mechanical skill'—are so industriously employed.

We glance at the moulding loft, where the plans of the ships are enlarged and laid down to full size to give the patterns for the foundry, and once more entering the ordnance yard, stroll round a gun lying ready to be taken to the shears and shipped. In the course of its building it has undergone 220 distinct operations, and is now passed as proved. Its sale price is a fair fortune—perhaps £20,000 or more. Blocked up on the trucks it seems to crush them with its weight. For a ship to carry such a load is a serious matter. But the giant crane will lift it in its beak as if it were a child, and place it with all due gentleness on the floor of the hold. There it will be packed and secured so as to be unshiftable in a sea-way, and there it will remain until it reaches its destination, when it will be picked out by other cranes to ride in a carriage of its own, and become the pride of its friends and the terror of its foes.

Down the Tyne is Mitchell's old yard at Walker, belonging to the Armstrong Company, who have thus two shipbuilding establishments on the river. In this yard between 2,000 and 3,000 men are employed, and 30,000 tons of shipping can be turned out each year. Here were built the Faraday, the huge double-ended cable-ship of 9,000 tons displacement; the Silvertown, another cable-ship, formerly called the Hooper, whose building took only 100 days; the Hankow and St. Osyth, the first full-powered vessels to make the Australian voyage; the Staunch gunboat; the Tyne trooper; and some 400 other vessels, including more foreign war-ships with unpronounceable names than any dockyard in the world.

Among the more recent foreigners have been those

patterns of swift armed cruisers, the Giovanni Bausan and the Esmeralda. Judged from her model and her photograph, taken instantaneously as she was flying through the water at over eighteen knots an hour, the Esmeralda is all such a vessel should be. Her size, 3,000 tons, is not out of the way for the work she is designed for; and her armament—two twenty-six-ton breech-loaders, six five-ton breech-loaders, two six-pounder Elswick rapid-fire guns, and six machine guns—is the most powerful carried by a ship of her class. Designed, built, engined, and armed by the Armstrong Company, she is naturally looked upon by them with considerable pride. When the lamentable weakness of our Navy was lately revealed, and the first steps taken towards its re-establishment, this ship was in the forefront of the battle of the types. 'Sixty Esmeraldas' one gallant admiral required for the protection of our commerce; and while other authorities were satisfied with a lesser number, all agreed that she could manœuvre round our own cruisers and attack them at her ease, and that unless we possessed some ships to equal or outsail her, our trade would be at her mercy.

It may be said that these cruisers, with their military masts and protected tops, are not particularly beautiful. Perhaps not; but beauty after all is a matter of the age in which we live. The past is always beautiful, and sailing-boats were never so nice as when they were first invented. When the Phœnician maiden went floating out to sea with her lover, and the fair Phœnician, holding out her drapery, stood in the bow of the boat as swiftly it drove to shore, surely the rig of the cruiser was at its best! The lady's drapery gave us the lateen—a graceful sail, but nothing to compare with that it took the place of. The lady's graceful figure in time became the mast—was that an improvement? The arms became the yardarms—another atrocity!—and eventually to those arms there came the stunsail booms. Alas! And at every change man sorrowfully thought of the beauty he had lost. Now all the old canvas has gone, with its snowy wings from the watersails to the moonrakers, and we have to console ourselves with a flattened funnel and a drum-headed pole, both assuredly to disappear in the onward march of invention!

CHAPTER II.

THE FORTH BRIDGE.

FAREWELL to Armstrong's and the Tyne; 'the morrow brings our greeting to the Forth.' Between Newcastle and Edinburgh great is the difference! But the odiousness of comparisons is proverbial; let us to work.

The Forth Bridge is as long as from the York Column, in Waterloo Place, to St. Paul's Cathedral. Stand at the column, and look up Regent Street, the distance to the Fire Office in the Quadrant is the exact width of one of the spans of the mighty bridge. Build the column until it is three times as high as it is now, and you will have the height of the great towers. Place the column half-way up the hill, as if under one of the spans, the arch that will spring from the pavement where you stand to the pavement on the hill-top will easily clear it; and if the road were the river you might sink the column vertically till it disappeared, for before it touched bottom there would be seventy feet between the surface of the water and the spike on the statue's head. In fact, you may stand St. Paul's at the base of that sunken column and the bridge will overtop the cross.

One of the uses of the Eiffel Tower which did not occur to the mind of its designer is that it serves as a convenient measuring-rod for objects greater than itself. Hang six Eiffel Towers horizontally on granite piers; make them so strong that five of our largest ironclads can be hung on to them to swing in the air; join them end to end with girders, and form a roadway from shore to shore, and you have the

bridge that Sir John Fowler and Sir Benjamin Baker have built to supply the missing link in our railroads to the North.

On the 28th of December, 1879, the bridge over the Firth of Tay was swept away in the raging storm. The engineer of that ill-fated structure had also designed a bridge across the Firth of Forth, and some preliminary work had been entered upon. It was to be a colossal suspension bridge, with towers nearly 600 feet high, on Inchgarvie, from which the chains were to drop in a graceful curve to the Fife and Midlothian shores. But with the Tay Bridge went much of the designer's reputation, and the promoters of the Forth undertaking grew nervous, and the plans were referred for reconsideration, and, in short, the suspension bridge was abandoned, and an alternative plan found favour. The alternative plan was that of the bridge now erected. Eight years ago, in 1882, the work began; on Thursday, the 26th of September, 1889, a workman placed a ladder loosely on the jibs of two opposite cranes and crossed the gap; and shortly after the bridge was completed from end to end.

It will be remembered—or if not, it may as well be assumed to be remembered—that Sir Walter's Monkbarns finished his lecture on *castra stativa* and *castra æstiva* at Mr. Mackitchinson's, where he had been deposited by the Hawes fly or Queensferry diligence; and it will also be remembered that it was at this same inn that David Balfour made his first acquaintance with Captain Hoseason of the brig Covenant of Dysart. This very inn is now at the foot of the Forth Bridge.

From the Fife shore the Ferryhill peninsula juts out, and narrows the Firth to the width of a good-sized river. To the west is a land-locked haven; to the east is the North Sea. Between the peninsula and the southern shore is an island; and hereabouts, for 800 years at least, there has been a ferry which has given its name to the villages on each bank.

Queensferry—South Queensferry, that is—is a royal burgh which has seen reverses. The queen from whom it had its name was the Saint Margaret, the daughter of the Ætheling in whom William the Norman took such male-

volent interest. She married Malcolm Caenmore; and while her father gave his name to Port Edgar, the little harbour to the westward, she gave hers to the ferry and to the anchorage which is still known to mariners as St. Margaret's Hope. That the ferry might be in neutral hands, her grandson, Malcolm, gave it to the monks of Dunfermline, with a subsequent reservation that the monks of Scone should always cross without fee. In those days Queensferry prospered, but of late life had not been cheerful in it; and in 1881 the royal burgh actually went bankrupt, and had to shake off its creditors on the terms of five half-crowns in the pound! That, however, was its dark hour before the dawn, for next year the building of the bridge began. It was then a home for under 2,000 people, lodged in two streets that crossed each other. Over the Firth is North Queensferry, on the peninsula, a village of about as many people as there are days in the year. After Paul Jones, on mischief bent, was blown out of the Firth—by wind, not by gunpowder—in 1779, North Queensferry was strengthened by a fort; and a fort was also built on the island of Inchgarvie, the old castle on which had once been a state prison. When the bridge works began, Inchgarvie castle and the battery were roofed over and made into comfortable habitations, and the Queensferrys, North and South, awoke from their nightmare of neglect.

For eight centuries and more men had been satisfied with the ferry, but in 1808 a proposal was made to drive a tunnel under the Firth to Rosyth sufficiently wide and high for horse and foot traffic—a scheme far too venturesome for the financiers of those days. What could not be done for the turnpike might, however, be done for the railroad when the traffic became pressing enough; and the idea of the tunnel was only abandoned, or postponed, when the possibility of a bridge became clear.

The site of the old ferry, with its peninsula and island, seemed made for a bridge. But the difficulty was how to deal with the depth of water, or how to get a span which would avoid that difficulty. The Forth is not the longest bridge. That honour, at present, belongs to the new Tay bridge, which is two miles and fifty-two feet long; but then the

Tay has forty-one piers, and its middle spans are only 245 feet wide. The Forth is not the highest bridge. It is twice as high as the Newcastle High Level; but there are higher. It is the span which gives it its pre-eminence. Roebling's great suspension bridge at Niagara Falls has a span of 821 feet; the famous Brooklyn Bridge has a span of 1,600 feet; the two main spans of the Forth Bridge are each of 1,710 feet. The gigantic suspension bridge of Sir Thomas Bouch solved the difficulty of the span, and for it the Act of Parliament was obtained in 1873; it was then the only method in practice of bridging such intervals; but at the reconsideration of the scheme the present method was proposed, and it was at once admitted by the majority that the new idea was better than the old.

A new idea it was thought to be, but not for long. As soon as it was published it was pointed out that the system had been known for centuries—of course in China; and then Japan and India put in a claim; and then—most unlooked-for discovery—it was unearthed that as recently as 1810 a Mr. Pope, poet, not of Twickenham, but of New York City, had proposed to span the East River at New York on the same principle, and had not only exhibited a model showing how it was to be done, but had even written a poem, as well as a specification, in which he announced that 'Each semi-arc is built from off the top, without the aid of scaffold, pier, or prop!' But, somehow, Mr. Pope had been forgotten, like the Hindoos, Chinese, and Japanese; and with the Forth Bridge the plan first took its place in modern engineering. And since its publication every long-span bridge in the world has been built on its principle.

That principle is obvious when we look at the bridge; the colossal cages are built outwards from the piers in such a way that their arms balance each other. If a weight be placed where they join when finished, there will be a pull along the top of the cage and along all the bars hanging downwards, and a pressure along the bottom of the cage and on all the bars thrusting upwards. Wherever there is a pull a lattice girder is used, wherever there is a thrust a tube is used; consequently all the members of the great trellis-work that diverge upwards from the top are girders,

and all those that diverge upwards from the bottom are tubes.

A cantilever is practically a bracket; the brackets are placed base to base, and balance each other, and get their anchorage at their extremities. But in the Forth Bridge the brackets are brackets of Brobdingnag; the tubes that look like slender spars are twelve feet in diameter, and the seemingly trifling granite piers that in groups of four carry this mighty object-lesson in permanent stability are sixty feet across.

The Inchgarvie tower is 260 feet wide, the towers on each side of it are 145 feet wide. The bridge, which has twenty acres of paintable surface, consists of nineteen girder spans and seven masonry arches. The masonry arches account for 395 feet of length; then there are eleven horizontal girder spans each of 168 feet, two of 173 feet, and two of 179 feet, ending at the masonry piers on each side, which rise to 209 feet above high water. Then come two single cantilever spans, each of 689 feet 9 inches; and then the two great double cantilever spans, each of 1,710 feet, for 500 feet of which there is a headway for navigation of 150 feet at high water.

When the bridge was begun by the contractors, Messrs. Tancred, Arrol, and Co., in 1882, their first step was the laying out of the shops and building yards along the bank, 100 feet above the Forth, with a wire-rope railway to the river. These grew as the work progressed, and for years the Edinburgh folk, at the cost of half an hour's ride from Waverley, had the opportunity of witnessing the whole process of bridge-making. Ordinary bridges are delivered from the foundry ready for erection, but the Forth Bridge was much too big an affair to be dealt with in the ordinary way.

In January, 1883, the foundations were commenced. For the piers for the shore spans in shallow water, timber coffer-dams were used; but six of the circular piers out of the twelve required under the three towers were constructed by means of pneumatic caissons. The making of these caissons—'cassoon' is the workmen's rendering—was the first noteworthy undertaking, and great was the excitement

when one of the gasometer-looking cylinders, seventy feet across, was launched and floated out into position, with the men clustering round the rim, cheering and gesticulating as the great iron tub slowly voyaged across the stream.

The caisson is really a diving-bell. Seven feet from its lower edge a floor is laid in it. Into the space below the floor compressed air is driven, so as to keep it clear of water, and in this space the men work. Communication with the upper floor is had by means of an air-lock, a contrivance with two sets of gates, on the same principle as the familiar water-locks on our rivers and canals. We enter the lock from without, and the sliding door is shut behind us; the air is then of the normal pressure, but when the inner door is opened the compressed air fills the chamber, as our ear-drums immediately tell us if we forget to keep our mouths open, so as to equalise the pressure within and around us. The doors are interlocked like points and railway signals, so that both cannot be open at the same time. Descending into the space below, we find the men—mostly Italians and Belgians from the Antwerp Harbour Works—at work in the full brilliancy of the incandescent electric light. The hard whinstone is excavated by percussion drills and dynamite, and raised through the air-lock; the hard boulder clay is cut into by the hydraulic spade; the mud is thinned with water, a pipe communicating with the upper air is laid in the dirty puddle, a valve is opened, and away aloft the mud is driven by the atmospheric pressure. Down sinks the caisson as the ground is cut away beneath and within it. As it sinks it is loaded above with concrete. It has an inner skin seven feet from the outer skin, cut up into pockets by diaphragms, so that the pockets can be loaded at any part where extra pressure is required. Where there is a gap the air escapes in an ascending stream of bubbles through the river. Attracted by the bubbles and the light, an enterprising salmon comes in to see what it all means. Instantly the navvies become fishermen, and in a few minutes the inquisitive fish has paid with his life for his pardonable curiosity.

Working below water is not without its dangers. The excavation must be regular, so that the caisson does not

cant. One of the caissons once dropped seven feet with a jerk, much to the alarm of the men; but the only fatal accident was with the south-west Queensferry caisson, which grounded as it was being floated into position, and collapsed, and killed two men as it was being pumped out. To start the sinking caisson with a level floor, sand-bags were used to fill in the slope; and then the cutting away of the clay and whinstone soon bedded the rim in safety. Once a gentleman brought a flask of whisky down with him to drink success to the new pier; the success and the whisky he drank, and he corked his empty flask and placed it in his side-pocket; he entered the air-lock, the door was shut behind him, the outer door was opened, and bang went the whisky flask. He was again under normal pressure, and the air from below would have served him as it had done his flask if he had similarly corked himself.

When the caisson had sunk into position—eighty-eight feet below high-water mark was the greatest distance it had to go—it was filled entirely with concrete made of whinstone from the Fife quarries, and sand and Medway Portland cement, of which latter no less than 30,000 tons were used for this purpose; even the mining chamber was rammed full of this material grouted up under pressure. Then on the solid drum of concrete came courses of flat bedded Arbroath stone faced with Aberdeen granite. And on this granite pier, now reduced to sixty feet across, were laid the bed plates of steel—massive slabs like armour plates, bolted down by a forest of steel bolts built round for many feet deep in the concrete and masonry. And then the bed plates were smoothed by emery wheels and coated with crude petroleum to keep them slippery, and on them the skewbacks were bolted in elliptical holes, so as to provide for whatever contraction or expansion change of temperature might cause in the great bridge.

Great bridge indeed! For from the base of the deepest pier to the top of the tower above the height is only ten feet less than that of the great pyramid of Cheops. Other bridges may be built to beat it in size, but it will always be famous as the bridge in which the difficulties of cantilever construction in steel were first overcome.

The Eiffel Tower is built of iron, and therein is behind the age. The Forth Bridge is built of steel, mild steel from three-quarters of an inch to an inch and a quarter thick, in plates and tees, and angles and channels—half-inch plates that can be folded like newspapers, and rivet bars that can be tied into knots without a sign of fracture. Altogether there are some 53,000 tons of steel, most of it from the Steel Company of Scotland, and some of it from the Welsh works at Landore.

There is not a perpendicular line in any of the cantilevers. In the skeleton towers the bases are 120 feet apart, while the tops are only thirty-one and a half feet, and all along the sides slope inwards. The rising members, the members that withstand the compressing, are, as we have said, all tubes. Joining the piers is a tube twelve feet in diameter; rising from this at a right angle, but with an inward batter of one in seven and a half, are the two main members; and in continuation of it is the lower member of the construction, which starts at twelve feet and gradually tapers off till its diameter is but five feet. Bracing the two main members diagonally are two flattened tubes eight feet in diameter; and midway between the main members and the lower tube rise two struts each eight feet in diameter. The junction of all these tubes on the bed plate forms what is known as the 'skewback.'

The tubes are built of plates. There are six miles of tubes, and forty-two miles of plates to build them with. The cross section of a twelve-foot tube shows that it consists of ten plates and ten longitudinal H-beams stiffened at intervals of eight feet by circular girders made up of diaphragm plates. The plates are sixteen feet long by four and one-third feet wide, and from one and an eighth inches to one and a quarter inches in thickness; they weigh from twenty-eight hundredweight to thirty-two hundredweight each. The H-beams are deep webbed tees and two angles.

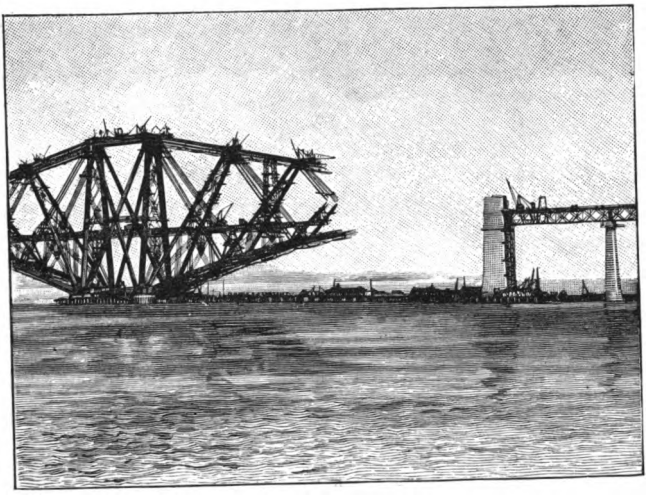
In making the tubes the plates were heated in a gas furnace, and bent while hot between dies in a hydraulic press. They ought to have retained their curve, but they did not. As soon as the blocks were removed they would warp longitudinally and bend erratically, one plate some-

times behaving in just the opposite way to its predecessor. Many things were done to prevent this, but in vain, and at last a lot of plates were curved at once and laid one on the other in layers with ashes between, and left to take their chance. When they were cold they were squeezed into shape by another hydraulic pressing, in which the desired result was obtained by using thin slips of iron in just the same way as a printer uses his overlays.

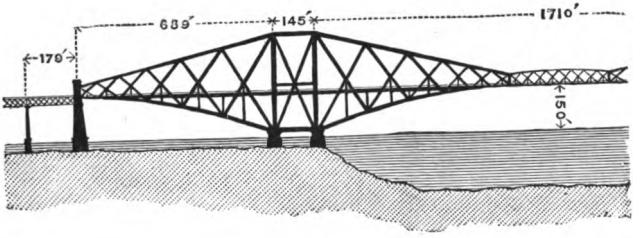
This pressing—the force was that of 1,600 tons between the dies—was done at the works near the Hawes Inn. And not only were the plates pressed, but they were planed and built up into position, and had the rivet-holes drilled before they left the shore. The scene at the yard can, therefore, be imagined. What with planing machines, and dressing machines, and the circular saw cutting slabs of solid steel, and the hydraulic rams justifying plates, and the rams curving angle-irons, it would have been remarkable even without the great drilling machines which were its chief feature. The tubes, as we have said, were built up on a mandrel just as if they were in position, but so large were they that, instead of being taken to the workshop, the workshop was brought to them, and travelled along them as they were constructed. This workshop had its own engine and boiler, and its own system of drilling machines; and the travelling annular drill-frames, each with ten drills kept cool by water jets, bored at a rate that would have sent the inch drills through 280 feet of solid steel in twenty-four hours, and made holes at once through plate and cover and stiffener, so that when erected not a piece would be a hairsbreadth out of position.

In setting out the bridge, which was done by triangulation and a re-survey by the Royal Engineers of their old work on the Ordnance Survey, an error was discovered in the map, and the line was taken further south than was intended; but as the error only amounted to ·79 of a foot, the difference, though regrettable, was near enough to 'no matter' to be disregarded. The work was begun all along the line. The viaduct piers at each end were raised to a height of thirty feet, the girders were placed on them, and then the masonry was carried up, taking the girders along

with it as it rose. This principle of utilising the permanent work as part of the scaffolding was characteristic of the whole construction.



THE FORTH BRIDGE IN BUILDING.
October 6th, 1883.



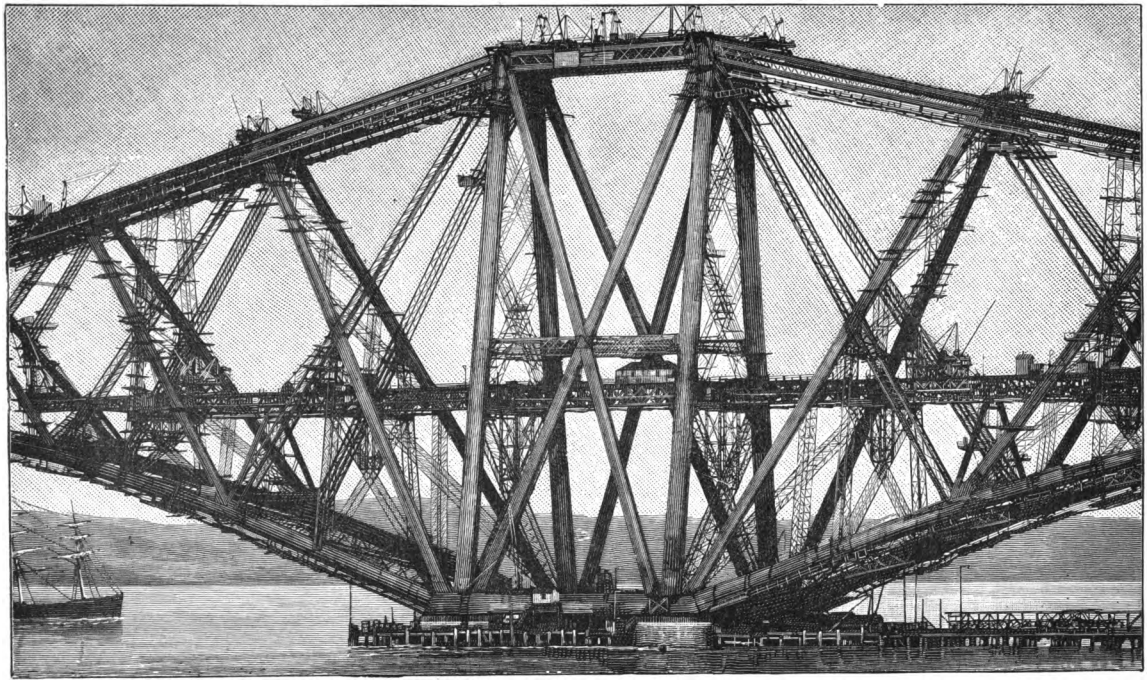
SECTION OF THE FORTH BRIDGE AS COMPLETED.

On the central piers work was started on the lower members, which were built out on the overhang. At the end of each tube a rectangular cage was hung, which

carried the riveting machine and the men at work, and had a crane on the top; and parallel to the tube ran a tramway on brackets, which brought the material within reach of the crane. The cage was in six sections; when the tube was completed within it, the two rear sections were taken off and placed in front; when the tube had grown to their limit, the next two sections were transferred in front of them; and this cage system was found to work so admirably that it was very largely adopted. As the bridge grew another plan was introduced. A platform of temporary girders 200 feet long was constructed for each cantilever, strengthened by supplementary trussing made from the links of old Hammersmith Bridge. These platforms, or working floors, were raised by hydraulic power, and consisted of two decks, on the lower of which were the sheds for work and shelter, and on the upper the gantries, cranes, and furnaces.

The furnaces for heating the rivets were oil furnaces, about four feet long, and half a yard wide, doing thrice the work of a coal furnace, and heating nearly 2,000 rivets a day. The work was all bolted into position and riveted hydraulically. In the smaller work the ordinary hydraulic pincers were used, but for the tubes a new machine had to be devised, in which there were independent rams for the holder and the snap; both worked along girders, so as to obtain the needful resistance, one girder being down the tube and the other outside; the rivet was inserted from the inside, and held in position by the holder, and the snap outside, at 1,000 lbs. to the square inch, gave the finishing pressure, and in this way eighty rivets were forced home in an hour.

Difficulties there were as the work went on. The sloping tubes had to be 150 feet high before they could be permanently braced, and their inward batter rendered them in constant need of adjustment by the hydraulic rams. Another source of trouble was in the setting out owing to the unequal expansion and contraction of the various parts of the bridge under the varying temperature; sometimes the centre line of the upper member would be to the east, sometimes to the west, of the true centre; and sometimes



From a photograph] SOUTH CANTILEVER, FORTH BRIDGE. *[by permission of Messrs. Spooner.*

October 6th, 1888.

the bottom member would be out of the true as it expanded unequally and receded from the sun.

But the bridge continued to grow, carrying the cages and platforms with it in its growth; and when the double line of way came to be put in, with its heavy bridge rails, on longitudinal sleepers, bedded in four steel troughs, into which the wheels ought to fall, should they leave the line; and the wind-bracing was fitted in its long diamonds of lattice; and the top junction girder began to get into position, with its auxiliary members; there was such a mass of steel work, permanent and temporary, such frames and floors, and uprights, and horizontals, and such a crossing of hydraulic pipes, and electric cables and ropes for staying and lashing, and running rigging and safety netting, that, instead of part of a bridge, the cantilever looked more like a giant weaver's loom, in which havoc had been played by an earthquake that had hurled it a hundred feet above the stream.

Night and day the work went on, 3,500 men clustering like flies in the steel tangles that rose in a line across the river; men in thick flannel jackets even defying the cold blast of the stormy Forth at midnight in mid-winter, that the progress might be unchecked. And the steel tangles looked more mysterious than ever did the network of a building bridge before, for they stood out cold and clear in all the sharp contrast of dark shadow and brilliant illumination that the electric light alone can give. A hundred arc lamps and 500 incandescent lamps gleamed on the bridge and in the shops—the largest outdoor installation then at work.

Every modern appliance was taken advantage of to get the bridge completed. There were telegraphs and telephones from shore to shore. There was a daily photographic record of progress. The quiet hydraulic press was brought in to do the work of a hundred noisy hammers; and there were compressors, accumulators, and rams hanging at every point of vantage. There were wire tramways and wire lifts, and there were steam winches and steam cranes, with jibs as manageable as a pelican's neck.

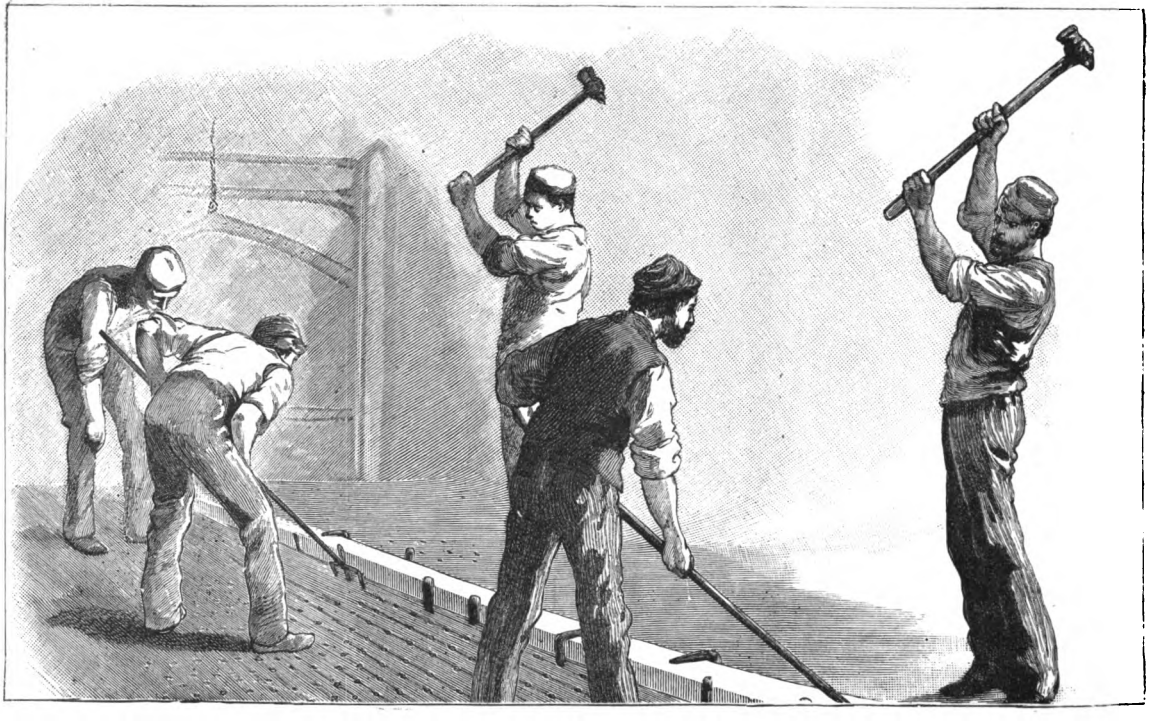
As the cantilevers were built out into space—one balancing the other, and trusting to the other for its only support—

with the cranes hanging over the furthest extremities, and lifting the material from the boats 300 feet below, the men looked like mice in a mill. They gave the scaling, but the mind failed to realise the colossal size of the structure, though to call it colossal is an insult, for the Rhodian figure could be hung in the waterway with the soles of his feet dangling half his height above high-water mark.

It was only when we were in the wilderness of work that the vastness of the construction was appreciable. The iron cage that looked like a bullet when aloft was found to be big enough for ten people when it dropped to take us up. The holes in the platforms, in their long series constantly diminishing one within the other, looked like an opened nest of Chinese boxes, and the upper ones seemed much too small to let us pass; but they did! Higher and higher through the holes, deck above deck we went, and when we stood on the top we looked down and caught a glimpse of the water only here and there among the multitude of interlacements. Immediately below us were the screens to catch rivets and hand-tools if they fell, as many of them were constantly doing; and further down we could see the covered ways designed to shield the workmen where the screens were missing. And around them, and between us and the river, hung such a complication of pillars and ropes and bars and wires as would never be forgotten.

As we moved outwards, right and left to the ends, it seemed as though our weight would overbalance the beam; but the ends have gone on lengthening, and further stretched their zigzags, and by the great 350-feet central girders have joined faces with the zigzags which stretched out northwards and southwards to meet them from the Queensferrys.

Since then the Prince of Wales has clinched the last rivet, and the bridge is completed. And the journey to the North is shortened by an hour. Such is the value of time in these days. All this work for the saving of an hour! Yes, but for the saving of an hour to every passenger that crosses the Forth and to every bale of goods. And the sum of those hours is considerable.



THE RIB ON THE BENDING SLAB.

CHAPTER III.

AMONG THE SHIPWRIGHTS.

ONE New Year's Day the Rotomahana struck fiercely on the sunken rock at the entrance of Fitzroy Harbour. She backed off and made her way safely to Auckland, leaking only through a few rivet holes. When she was docked it was found that for twenty feet of her starboard bilge the frames had been forced back, the bulkhead bulged, and the plate wrinkled. And yet not a crack was visible! The worst-damaged plate was taken out, re-rolled, and replaced; and the repairs were finished perfectly in seventy-two hours. Had she been of iron, such a rent would have been made in her that she would have filled in a few minutes. Her accident marks a new era in the advance of navigation. The Rotomahana was the first steel ocean-going steamer to come to grief. By her dangerous experience the immense superiority of steel over iron was manifested; and now all our ships are steel built. They are safer than iron ones; there is less risk of loss with them; and being lighter than iron ones their earning power is so much increased that they soon repay the additional first cost.

For the rise of the new machinery we must go further back. The first compound engine appeared in 1856. Then for the first time was it shown that two cylinders, like two heads, were better than one, providing they were not of equal capacity. The principle is simple enough. The steam admitted into the small, or high-pressure, cylinder, is cut off at a fraction of the piston-stroke and passed on into the larger

cylinder—the reduced power on the increased area of the low-pressure piston doing as much work as the greater power on the smaller surface of the other. This ingenious arrangement of unequal cylinders, which had among other merits the important one of reducing leakage and loss to a minimum, did not come into general use till 1869, and it was not till 1872 that it was adopted by the Peninsular and Oriental and Cunard companies. Now it is universal; and the result we see in the wonderful passages made by our passenger boats, which every year become speedier. The adoption of mild steel and the invention of the compound marine engine are the two main facts in the history of the modern ship.

With the introduction of both, the Clyde is closely associated. The Clyde first saw the Comet which heralded the advent of steam navigation, and since the days of Henry Bell it has kept the lead in the new art. It is a river of ship-yards. A few years ago ship-building appeared to be too good a thing to be kept amongst a few, and now there are so many to share the trade that a 'depression' is the result; and along the river bank there is many a clump of gaunt staging rotting in the sun, and, like the saplings of the Indian's burial-place, telling of the departed 'she.'

But in many a yard, famous the world over, the hammering of the shipwright echoes across the stream and tells of work steadily progressing. The most famous and flourishing of these yards is Elder's, at Govan, now belonging to the Fairfield Shipbuilding and Engineering Company, Limited; and when it occurred to us to learn how a steamship of to-day came into existence, it was to Govan that we naturally went. We were there, with much courtesy, given every chance of studying from the life a very interesting subject; and we herein purpose telling what we saw during our day among the shipwrights.

Elder's had but just completed its jubilee when it became a limited company. In September, 1834, Mr. C. Randolph and Mr. R. S. Cunliff began their partnership in a small millwright's business. The first job came in the first day. It was not an extensive one. It realized the sum total of sixpence; and the profit on it was just sufficient to pay for

the mutchkin of whisky in which the partners drank success to the new firm. The success required little seeking; before the year was out the firm had paid their fast-increasing men over £1,000 in wages.

In 1852 Mr. John Elder became a partner, and the millwrights began to make marine engines. Eight years afterwards, in the yard now occupied by the Govan Shipbuilding Company, the firm began to build ships to put the engines in, the first vessel being the Macgregor Laird, for the African Mail Company. In 1864 business had increased so much that a move had to be made to the present yard; and the first vessels there built were four blockade-runners, which were sent away complete within six months from the date on which they had been ordered, one of them, the Falcon, having quite a history attached to her. This was quick building, but is nothing like the speed since attained. When, in the days of Khartoum, the dozen stern-wheel boats were ordered at Fairfield for the Nile Expedition, the first boat was passed by the Government Inspector within three weeks, and the twelve were built, tried under steam, taken to pieces again, and shipped on board the Parthia within thirty-eight days of the day that the first instructions had been received for them. And in building larger vessels the speed has been as largely increased, so that it now takes but nine months to turn out, fit for sea, an ocean-going, record-breaking mail steamer. In 1878 the late Sir William Pearce, formerly a Royal Dockyard student and Lloyd's surveyor, became sole owner, and the business underwent immense development. By keeping the yard going on vessels for sale, the men and machinery not only continued at work, but a wider scope for experiment was offered than if the ships had been built solely to order; and a fleet was launched annually, each vessel of which was an improvement on the last. From the owner's connection with the Guion and other steamship companies, there was no difficulty in employing the newcomers; and the result was a keen competition with other lines and other builders, forcing on a raising of the record for convenience, comfort, and speed, of which all men have enjoyed the advantage. During the seven years of the sole

proprietorship Messrs. John Elder and Co. launched into the Clyde over £6,720,000 worth of shipping! Surely at Fairfield we should learn how a modern ship is built!

In the first place, then, how does a ship begin? She begins on paper—like many other things. The naval architect designs the ship. He is furnished with particulars as to capacity and approximate dimensions, and, on a scale of a quarter of an inch to a foot, he and his assistants at length produce three construction drawings—sheer plan, half-breadth plan, and body plan; the first giving length and height, the second length and breadth, the third height and breadth. With such drawings most of us are familiar. The drawing-office at Fairfield differs from other drawing-offices chiefly in its display of beautiful models of ships built in the yard—which models are made in a special joiner's shop close by. The very full series shows the rapid strides by which the size of ocean steamships has of late years increased. Nearly all of them are to a quarter-inch scale, so that comparison is easy. Here are the middle ages of steamship building in the paddle-boats Islay and Oroya, 265½ ft. long, and about 1,600 gross tonnage, built for the Pacific Steam Navigation Company for the South American trade. Here are the Tagus and Moselle, built for the Royal Mail Company, 340 ft. long, and of 3,300 tonnage. Here are the Chimborazo and Cuzco, now in the Australian trade, 370 ft. long and of 3,800 tonnage. Here is the Austral, in the same trade, 455 ft. long and of 5,600 tonnage. And here are the Etruria and Umbria, 500 ft. long and of 7,700 tonnage. And among the other models are many of our warships now afloat, and that strange freak of naval architecture, the turtle-shaped Russian yacht Livadia, of 11,800 tonnage and 12,383 horse-power.

But it is with the ships of the present we have to do. Let us follow the drawings to the mould-loft, a broad, low-pitched room, over 100 yards long, the most important part of which is its floor. This floor is a gigantic drawing-board, on which the plans of the ship are drawn at full size, or forty-eight times larger than they leave the draughtsman's hands. It is a huge blackboard, on which the work

is done in white chalk, the lines of flooring coming in useful for measuring purposes, and being therefore more carefully laid than is customary with ordinary floors. The object of transferring the plans to the mould-loft floor is to 'fair the ship,' that is, to detect and rectify any error or oversight that may have been made in the small scale-plan. Errors unnoticeable on a small scale are here increased into visibility, and rectified by a judicious mixture of give and take. A quiet, orderly place is the mould-loft, with a look of 'tween decks about it; the light from the long range of dwarf side-windows slanting in on to the wide clear space on which the full height of the future vessel is shown in complicated tracery, line upon line. Along under the windows runs a broad bench; and at the foot of the bench is screwed the permanent base from which the measurements are taken. The straight lines are got by cords and rules; the curves by bending battens so as to pass through certain points, nailing them in position, and then chalking along their edges. Every line necessary to be known in building the hull is here laid down, and checked and counterchecked until it fits exactly and answers all the requirements of the design. To lay a large ship off on the floor may take five or six weeks, so carefully has the work to be done; and no care can be too great, for the result is the working drawing, from which no departure is allowable.

When the lines are passed as accurate, moulds or skeleton outlines of them are taken, and thus they get transferred to the 'scrive-boards,' from which the shipwrights work. The chief scrive-board—the only scrive-board in many yards—is that containing the body-plan. It is a drawing-board, made of seasoned deals clamped firmly together, on which the lines are first chalked and then carved, or scribed, much as the marks are placed on cask-heads. By this means erasure is rendered impossible. To minimize the confusion in the thicket of lines, the different series of marks are often painted different colours. The board is the same size as the section of the ship at her widest and deepest parts, so that for an Atlantic liner it may reach the modest dimensions of fifty feet by forty. A nice little drawing-board!

This board, big as many a church floor, and so smooth and thickly cut into that it looks as though it were to be printed from, goes to the machine-shop. What a contrast is here to the quiet of the mould-loft! We are in a long, airy smithy, 1,000 feet from end to end, and fifty yards wide. Ship-building requires space, and there is no crowding of the machinery; but over the wide area we see a fortune strewn in furnaces and smithy fires, bending rolls, planing-machines, drilling-machines, punchers, squeezers, shearers, and countersinkers, all of mighty size, for there is no small work here. One side is a dead wall, the other is open to the river, and faces the bows of the new ships now growing along the shore. The shed echoes with the clangour of metal, which for a moment overpowers the never-ending racket from the riveters on the ships. The men are at work in groups. Every now and then a thin snake of fire seems to writhe amongst them, and the faces glow in the glare of the steel, and then the glare fades and the daylight asserts its mastery. A few years ago, when ship-building was a mania, and even our maid-servants held 'sixty-fourths,' this Govan shed was thick with workers. Now but a third of the full number are here, and many of the machines stand idle. 'But there's a good time coming,' we agree, when we are shouted at to stand aside, and past us dashes one of the fiery snakes, a length of angle steel from a reverberatory furnace that for an instant has opened its jaws and shown the fire that rages behind its dull-looking face of brick.

On the ground, like a platform, lies the scrive-board; close to it is the 'bending-slab'—a pavement of square masses of iron, each weighing many tons, and so fitted together as to form a perfectly level floor of dimensions large enough to take any frame required in the ship to be built. Its surface is so perforated with peg-holes as to give it the look of some new kind of cribbage-board. The holes are in thousands, and are about six inches apart and an inch wide; and the resemblance to the cribbage-board is increased by the pegs scattered about in them and on them. In the enormous shed, with the big scrive-board and this huge bending-slab, the men are dwarfed considerably, and

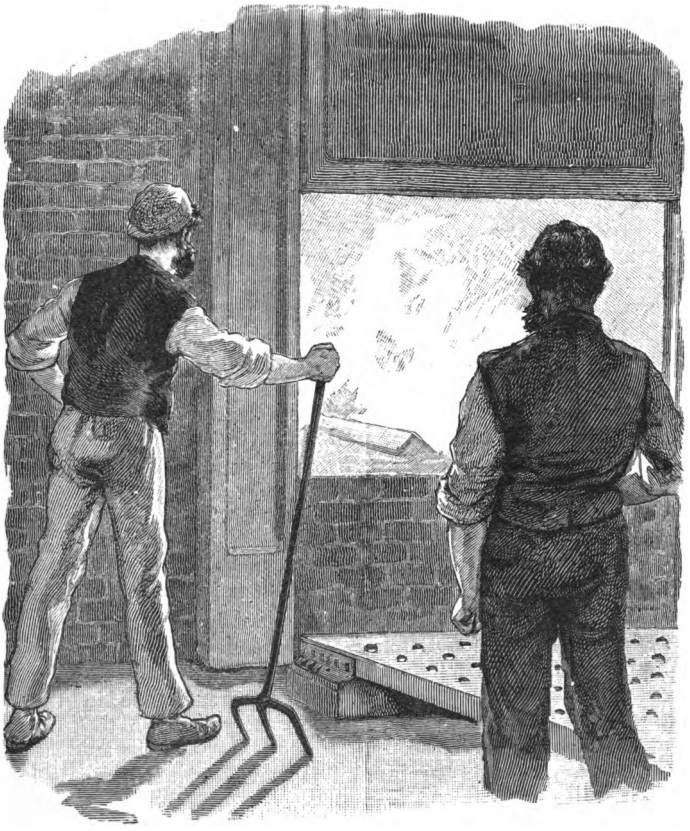
a feeling that we are among the gnomes comes over us. But we return to reality by way of a hint as to 'gnomonic projection,' and watch the curve being formed on the slab.

On the platform there is laid a pattern, answering to one of the frames shown on the scrive-board. The curve passes every now and then close to one of the innumerable holes in the face of the slab. Into these holes iron pegs, or 'dogs,' are slipped, and so many are they that the full swell of any curve can be given without flatness. The slab, thus set up with its pegs, is ready for its work.

From the furnace comes the long red bar of angle steel. It is thrown on the slab, and, with heavy-looking three-pronged forks, pressed by the men against the curve of pegs. It yields mostly as if it were putty. Where it is obstinate the prongs of the fork get sufficient purchase from the holes in the slab to lever it into the shape desired. If it bends upwards the hammer is used. So close are the pegs that the curve is a true one. Beyond a certain allowance made for contraction in cooling, the bend of the red bar is that on the scrive-board, and therefore that in the mould-loft. It soon cools, is compared with the scrive-board, and removed. Before the pegs are shifted the frame for the other side of the ship is bent in the same manner, so that both sides must correspond. Then the bending-slab is cleaned; a new curve is pegged out from the next pattern; another bar issues from the furnace, and writhes into another rib, to be followed by its twin-brother. So the work goes on. To compare the making of a rib in this style with what it used to be in the time of the old wooden ships is surely enough to take one's breath away!

Before the angle-bar is bent the rivet-holes are punched in it, each about eight diameters of the rivet apart; and if the frame is to come near the ends of the ship, where it is required to be much bevelled, the bevelling is also done prior to the bending. Every frame is proved on the scrive-board, and its curve made exact, should it vary in the slightest degree; and when it is passed as correct it is marked with the chisel to show the position of the

plate-laps, ribbands, stringers, and deck-beams we shall meet with as we go.



NEARLY READY.

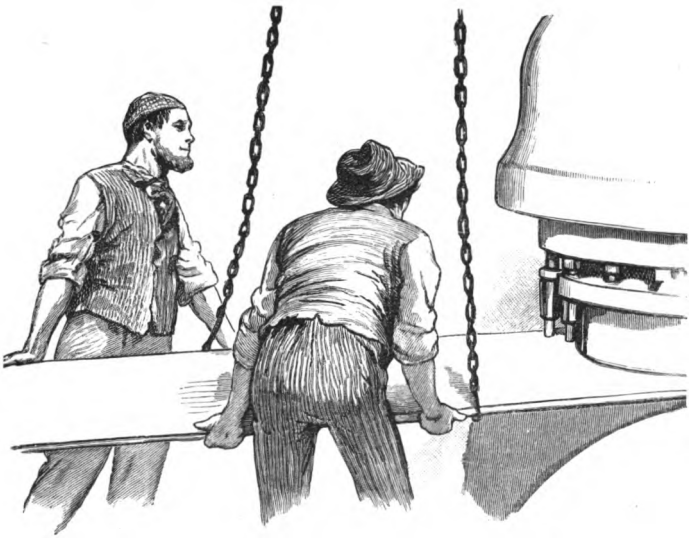
To shape the plates very different machinery is required. First they are straightened in a massive mill having seven rollers, which treat them in mangle fashion, and turn them

out, thick or thin, quarter-inch or inch, true at one operation. If they are to be curved lengthways or widthways another roller arrangement is brought to bear; if they are to be curved both ways another ingenious shifting roller-mill is equal to the occasion. If they are too large they can be trimmed by the shears, which cut them as easily as if they were tin plate. If angle-bar has to be cut, it is put in a powerful double-motion machine close by, which nips off two bars at once. When the rivet-holes are required, they are punched ten at a time. When a man-hole is required, matters become serious; the plate is taken to a sturdy-looking steel workman, who knoweth not nonsense, and to whom the punching of a hole twenty-two inches by fifteen in a half-inch plate is but child's play. Verily, great is the power of hydraulic! Here is a hole, big enough for a man to slip through, squeezed out of a slab of steel with no more fuss than if the steel were piecrust! Before the plate is ready it must be planed, and by the side of the wall are the planes, to whose tender mercies it is entrusted for the removal of its little asperities. Figure these planes, and punchers, and benders, and slabs, and boards, and bars of glowing steel; add to them the wheelwork and gearing, the pipes for the hydraulic, the cables for the electric light, the furnaces and smithy fires, the steam-hammers and the forgings, the travelling cranes and the wooden rollers big as hogsheads, on which the work is rolled about, and you have the shaping-shop at Fairfield.

And now let us cross the double line of rails to the hulls in progress, and see how this framework of bars and plates is put together. All the steelwork of the ship is made in the shop except the fore and aft posts, which are generally, but not always, forged at such places as Beardmore's at Parkhead. As soon as the scrive-board is ready work is begun on the ship in many departments. When all work to the same measure there is no fear of a misfit. Simultaneously with the putting in hand of the frames and plates, the stem and stern frames are started on. If the stem is ordered outside it comes as a straight bar, and is bent in the yard. The stern frame has to come as it is to be fixed, and, with its rudder-post, body-post, and connecting-plate,

is a very cumbrous burden—so cumbrous, indeed, that Fairfield intends for the future to make it, whenever possible; and the pattern for the posts of the two Government cruisers in hand we see being made as we pass.

Fairfield Works have launched over 400,000 tons of shipping during seventeen years. In one year they have



THE HYDRAULIC PUNCHER.

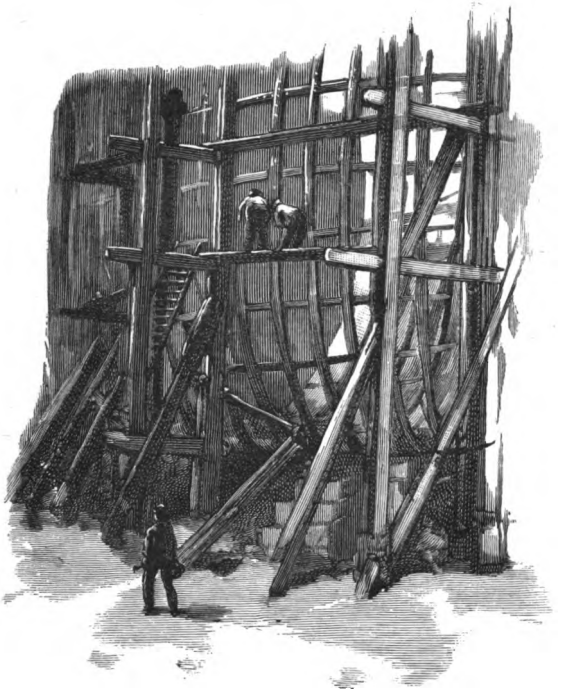
turned out a million and a quarter's worth of work, and the wages list has amounted to £375,000. They cover seventy acres, and have a river frontage of 400 yards. The Clyde is not a wide river, and, to get the greatest run for launching, the ships are built at an angle to the stream. Side by side are the slips from which scores of the most famous ships now afloat have been launched. The list is that of the cream of the British mercantile navy: the Ormuz, now holding the record for the Australian passage, the Orient, and Austral, all of the Orient

Line; the fleet of over fifty vessels of the Pacific Steam Navigation Company; the Etruria, the crack Cunarder; her sister, the Umbria, and the ill-fated Oregon; the Alaska and Arizona, of the Guion Line; the Kaikoura and Rimutaka, and the rest of the fleet of the New Zealand Shipping Company; the Norham Castle and Hawarden Castle, and others of Donald Currie's Line; the Fulda, Werra, Aller, and six others of the fleet of the Norddeutscher Lloyd; the Stirling Castle, of Skinner's Line, still holding the record for the China passage, owing to her extraordinary run with the tea cargo from Woosung to the Isle of Wight in twenty-nine days eleven hours.

But our present business is with the building of the ships, not with their triumphs of speed. How are the frames put together? Easily enough! A series of substantial blocks is laid as a foundation on good sound ground. If an ironclad or very heavy ship is to be built, it is in some places customary to drive piles into the ground to support the immense weight. These blocks are four or five feet apart, arranged so as to give a long slope of five-eighths of an inch to a foot, high enough for the men to work beneath the keel to be laid on them, and starting close enough to the shore to save the forepart of the new ship from striking the ground as her after part is waterborne.

In old days the keel of a ship was prominent enough to be unmistakable; when iron shipbuilding came in iron keels, smaller in size, but of the same shape, were adopted. In these days of steel the old keel has vanished altogether and gone inside the hull. The curve of a ship's body below water from side to side is now unbroken by any ridge. On the blocks is laid the flat keel, which is practically the centre-line of plating; on this is placed the vertical keel, and on this come the keelsons. The ribs are set up about two feet apart—from twenty to twenty-six inches—and at every rib the keel is crossed by the 'floors,' so that, though the keel itself is insignificant, the network of frame and reverse frame that takes its place is very strong. Sometimes the floors run right across, and then the steel girder known as the vertical keel gives place to a series of short

lengths between each floor. Such a keel is 'intercostal.' Where the floors run only half across, the keel is 'continuous.' Below the engine-room the vertical keel is always continuous, and it is continuous throughout in ships of war.



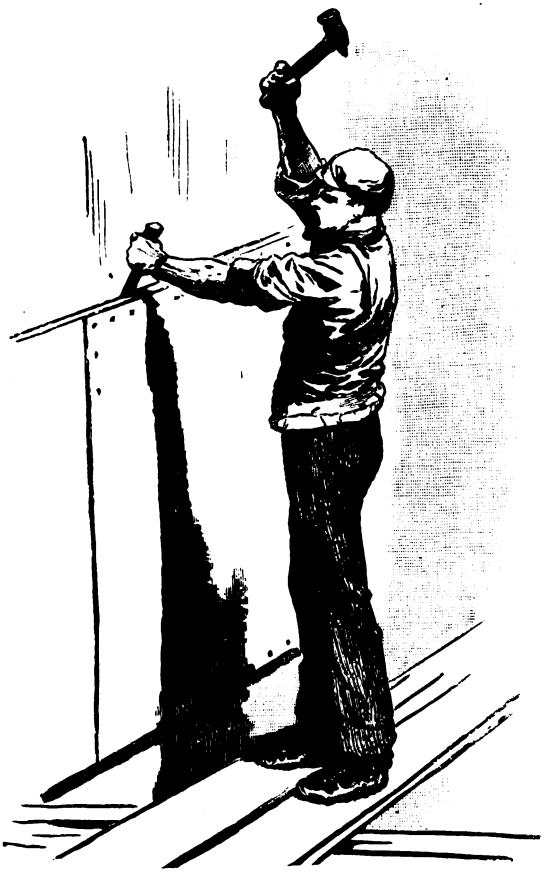
COMPLETING THE SKELETON.

As soon as the keel is laid down the work all along the line becomes visible; the stem and stern and ribs are set up, and the familiar form of a 'ship in frame' rapidly develops itself. It is then that the scene looks its busiest; na girders and angle-bars are not wide enough to hide the trah·en behind them; and the slender skeleton, with its forest

of ribs, is alive with its builders. But, thanks to the elaborate plans, there is no waiting for one stage of the work to finish throughout before another is begun. The frames are set up at right angles to the keel, and hence, owing to the slope of the blocks, slightly sloping aft. They are crossed and strung together by the 'rib-bands;' the beams and stringers of the decks are riveted into position; in the fore body and aft body there is much strutting and bracing, to prevent the new ship 'panting' in her struggles with the waves; and vertically and laterally, horizontally and diagonally, the thin steel angle-bars are laced and braced until the complicated plated basket is strong enough to brave any force that may assail it within or without. The great striking fact about a vessel's structure is the way in which the several parts fulfil their special duties, and at the same time strengthen each other. There is no better symbol of a well-organized state than a ship's hull.

In fastening the girder work the riveting can be done hydraulically. Silently and resistlessly the pincers grip the heads of the glowing bolts, and, with a quick, gentle squeeze, flange them and finish them. When it comes to the plating —the 'shell plating,' as it is called—the hand-hammer has still to be brought into play, and the noisy hammering of the shipwright is only second to that of the old-style boiler-maker. It is pleasurable to see how perfectly the plates fit the places assigned to them. They are shaped, as we saw, in the shed; they come to the slip, are hoisted into position, and with all four sides fit truly into the great curves as if they had been moulded there; great plates, six times the frame-space, fitting tight against each frame they cross, as if, instead of rigid steel, they were grey slabs of yielding clay. They are put on in 'strakes' or rows, each strake about four feet wide, and each known by its letter; the garboard strake, the one riveted to the keel, being A, the next B, and so on up the side. The upper edge of A overlaps the lower edge of B, and the lower edge of C overlaps the upper edge of B; in this way A, C, E, and so on alternately, have both edges exposed; while B, D, F, and the rest of that series, have both edges hidden; the lateral edges fit

flush with each other, so that there is no check to the clean passage of the ship. As the strakes are finished they are



THE FINISHING TOUCH.

'caulked,' the caulking being not with oakum, but consisting merely of the turning in of the sharp edges with a

chisel. As the plates are put in place they are secured with nuts and bolts through the rivet-holes, and these give way to the rivets. The holes are countersunk, so that the rivet is firmly held without the usual protuberance, and the side of the vessel is practically a smooth surface. As the plating closes in the skeleton from the outside, the decks and bulkheads fill it in within, all of them adding to its strength as well as to its safety. In sailing vessels there is generally but one bulkhead—the 'collision bulkhead'—a few feet from the bow; steamers can hardly do with less than four, but these are not necessarily in the same vertical line; on one deck they may be a frame-space or so farther aft or forward of what they are on the decks above and below. In warships there is generally a longitudinal bulkhead running down the middle from stem to stern, enormous strength being gained by thus practically carrying the keel up through the ship to form a backbone. As the bulkheads strengthen the ship, so do the steel decks. These are all caulked as if they were to be left exposed, and, to make assurance sure, they are thickly painted before the teak planks are laid on them. The well-caulked wooden deck, that triumph of cleanliness, is merely the casing of the real deck on which it rests.

Soon the mighty mass of steel takes recognizable shape and approaches completion, and the activity of its builders rises to fever pitch. As the hull closes in, cut up by these decks and bulkheads and strengthenings, hundreds of men are noisily at work, fitting and riveting amid a bewildering entanglement of temporary scaffolding and permanent structure, and a ceaseless hoisting and swinging and lowering of angle-bar, I-bar, Z-bar, or other bar gliding into its appointed place, as joist, or post, or beam, or stay, or strut, or stringer. Inside and outside the hull is veiled in a lacework of spars and chains dotted with workers.

As a rule the bow part is finished first, just as in fixing the frames the after post is set up last. In riveting the shell-plates to the screw-frame, the rivets go right through, so as to grip the plating on both sides; they are therefore very long; were they to be heated throughout, the contraction of the metal in cooling would be so great as to

drag off their heads, and to avoid this, the tip only of the stern-plate rivets is heated. Before the hull is launched, every one of the million rivets in it is examined, and, if found sound to the hammer-tap, is chalked, in sign of its having been checked.

When the shell is finished with all its decks and bulkheads and devices for giving it strength, preparations are made for the launch. Massive 'launching ways' are built on each side of the centre blocks on which the ship has been built. These ways are baulks of timber laid one on the other in a continuous line. They are in fact a pair of slopes down which the vessel is to slip into her home; and they are very strongly built, for they are to take and carry for a time the full weight of the completed hull. There is no break in the slope, the angle of incline is carefully adjusted, and planed till it is smooth as glass, and greased until it is slippery as ice. On this long slope the 'sliding ways' are fitted. These are smooth on their under side, and fitted with a flange on their inside edge, to prevent them from slipping outwards off the grease; and struts are placed extending under the vessel from the port to the starboard way, so that they cannot slip inwards.

When these sliding ways are in position sunk on the hundredweights of grease and tallow with which the launching slope has been 'paid,' a series of struts or 'poppets' is raised on them. These are wedged up and gradually take the weight of the ship off the central blocks. The central blocks are then cleared away, and the vessel rests on her new cradle, which is kept from slipping by a strut or 'dogshore' on each side, butting against blocks on the launching and sliding ways. To check her as she takes the water, and prevent her charging into the opposite bank of the river, hawsers and chains and anchors are used; and so tremendous is the force with which she slips that these anchors will sometimes tear open a furrow in the ground half as long as a cricket pitch.

A ship launch has been described so often that we need say little about it. A weight is hung high up over each dogshore, and the lines that hold the weights are brought round and joined at the bow, in front of which the platform

is erected for those who are to take part in the ceremony. As soon as the ship has been named, the cord holding the weights is cut, down drop the weights on to the dogshores and knock them out of their blocks; there is nothing then to keep the sliding ways from slipping down their greasy bed; down they go at ever-increasing speed, carrying the ship with them; and as the after part is waterborne the poppets fall away, and the vessel finds her destined cradle, not in the deep, but in the shallow, narrow Clyde, across which she gives every sign of rushing at a rate which would take her up high and dry on the opposite bank. But the anchors and chains and other instruments of restraint do their work; the great hull curves off to the left down stream; is brought to a standstill; and towed into the tidal dock which ends the long river frontage of Fairfield.

And then for a few months the ship is the prey of an industrial army. A dozen departments take her in hand and fit her for sea. Engineers, smiths, painters, carpenters, joiners, cabinet-makers, riggers, all work their will with her, and leave her a floating palace. We stroll through the woodworking-shops, where nothing is done by hand that can be done by machine. Mechanics, destitute of flesh and blood, grim, ugly, accurate, and untiring, are slipping through such quantities of work in an hour as would take the handworkers months to deal with. Here are things of straps and wheels sawing and planing, mortising and tenoning, chiselling and carving, with such speed, precision, and power as make us wonder what the future will invent. Many are the small improvements that have come from the inventive genius of the workman to build up these machines. One firm on the Clyde has a regular scale of small rewards to encourage inventions by their staff, and have given away over £500 in this way.

But 'the soul of a ship is her engines.' At Fairfield the engines come into life since 1870 represent an aggregate of over 450,000 horse-power. The pile of buildings which is their birthplace is fifty feet high and 300 feet square. The wonders of the factory are conceivable without detailed description. To the untrained visitor it is a bewildering box of tools of all sizes, shapes, and properties, from the

fussy polishers to the mighty borers that, in majestic leisure, scoop the cylinders that are to drive the hull of steel with the force of 10,000 horse-power. There are lathes of all kinds; slotting machines for working through great thicknesses of metal; a planing-machine twenty feet long for trimming armour-plates; a drilling-machine with a radius of eighteen feet, that will drive a four-inch hole in a nine-inch plate in half an hour; another with a traverse of fifteen feet by twelve; a boiler driller worked by four separate steam-engines that will deal with a shell eighteen feet in diameter. There are vertical boring-machines for perforating propellers; a lathe with a ten-feet spindle; one with a chuck sixteen and a half feet in diameter, another with a forty-one-feet shaft, and a herculean metallic disk, grimly named the 'devil,' armed with steel cutters on its circumference that takes off a pound of shavings at every revolution.

And now we move on to a smithy 300 feet long and 100 feet broad, with 100 smiths' fires, besides plate furnaces, forging furnaces, hydraulic cranes, and considerably over a dozen steam-hammers. Here, amongst the sundries, the masts and yards are turned out, for the spars of a ship are now all of steel—the masts a tube in three main longitudinal sections. Outside in the engineering-yard the cranes are busy, and the shifting they have to do may be realized when we consider that 20,000 tons of metal pass through their grip in a year.

In the tidal dock at the west end of the building yard, there is fitting out at the time of our visit a North German Lloyd liner, destined to reel off her nineteen knots an hour. Her engines are being built into her, a massive maze of mechanism true as watchwork, in which if a hole has been bored the eighth of an inch out the whole thing may be ruined. One of the cylinder caps is being lowered. A man is inside the cylinder—he looks as though he were in a well—and he is guiding the aim of his companions in getting the hole in the cap immediately over the piston-rod. It is a nice operation, and obviously requires careful adjustment; but it looks awkward for the man. The heavy cap hangs above him in mid-air; were it to fall, it would

bottle him up. But he might find very comfortable quarters in that circular well! Around him, deep down, the engineers are busy. The engines are of a new type, and this is the first vessel into which they have been introduced. There are to be four cylinders working on to three cranks—two high-pressure ones of thirty-two and a half inches in diameter, one of intermediate pressure sixty-eight inches in diameter, and two low-pressure ones of eighty-five inches in diameter. They are being built with the high-pressure above the low-pressure, tandem fashion, with a piston-rod common to both. The glands on the top of each low-pressure cylinder, with the glands on the bottom of its companion high-pressure cylinder, will be enclosed in a steam-tight casing, and the two pistons act as guides for each other, so as to do away with a guide-rod proper in the high-pressure cylinder. The place of the intermediate cylinder is between the others, and it will work on the middle crank. The shaft is in—or rather the shaft has been fitted together, for the shaft of a modern steamship is not a solid bar of steel, as is popularly supposed, but a length of many tubes joined together, several spare lengths being always carried on board, so that when a breakage occurs the broken length can be taken out and replaced by a new one. The propeller blades are of manganese bronze, that useful alloy whose employment has added a knot an hour to the speed of our steamships.

In one place the hatches are open right down, and we look into the forty-feet cavern, which is big enough to swallow a three-floored house, roof and all. In another we look into the saloon, which the cabinetmakers are panelling with satin-wood. We go below, deck under deck. In one place the plumbers are at work on the marble baths; in another the electric engineers are running the wires for the light; in another a mast is being boxed in by carpenters—it is slipped down into holes too large for it and then wedged up and the wedges trimmed up and hidden. In another the sleeping-bunks are being built; in another the pantry is being shelved; in another the cooking-stove is being finished off; in another the provision space is taking shape.

The number of people employed on a ship before she leaves the yard is remarkable. On the Etruria (7,700 tons) as many as 1,200 were at work at one time. There are not so many here, but there is room enough to stow away crowds. It is almost impossible to realize the stowage space of one of these huge liners. Even in such a minor item as the provision store the amount is prodigious. What it will contain in the present ship we can guess if we take as an example a recent stock list of the Etruria. Here is the little invoice for a voyage to the westward with 547 cabin passengers, the groceries serving for the voyage out and home:—12,550 lb. of fresh beef, 760 lb. of corned beef, 5,320 lb. of mutton, 850 lb. of lamb, 350 lb. each of veal and pork, 2,000 lb. of fresh fish, 600 fowls, 300 chickens, 100 ducks, fifty geese, eighty turkeys, 400 grouse, fifteen tons of potatoes, 1,000 quarts of milk, 11,500 eggs (being an egg a minute during the voyage), 650 lb. of tea, 1,200 lb. of coffee, 5,150 lb. of sugar, 1,500 lb. of cheese, 2,000 lb. of butter, 1,000 lb. of bacon, and 3,500 lb. of ham. We have no space for more items, but these will do as samples. Add to them over 1,200 dozen of bottles of wine and beer and waters, and you have a faint notion of one branch of the catering department.

What the coal space is like can be gathered from the consideration that the boilers use up a ton every five minutes, that forty-two tons of coal are burning in the furnaces at one time, and that to coal the ship for a double passage to New York and back requires a train of trucks extending for over two miles. To keep the furnaces supplied is the work of 112 firemen and trimmers; to drive the ship takes a dozen engineers; to work her there are carried four dozen seamen and seven officers. The space devoted to sleeping-rooms, and dining and recreation saloons, is enough to accommodate over 500 cabin passengers, to look after whose comfort and conduct there are employed six dozen stewards, half a dozen stewardesses, two dozen cooks and helpers, two masters-at-arms, and a surgeon. And for all these there have to be provided full facilities for efficient service. In all the three

departments—engineering, navigating, catering—the furnishing must be complete. The ship is a flying town, self-contained and independent of outside aid. The conditions of her existence do not admit of anything being forgotten.

No wonder that it takes an industrial army to fit for sea that complicated outcome of modern civilization—a first-class ocean liner.

CHAPTER IV.

THE FOUNDRY BOYS.

IN Glasgow we had a day of rest, and we spent it with the 'Foundry Boys,' which we had heard of as 'the most perfect of Sunday Schools.' The phrase is somewhat wide of the mark. The 'Foundry Boys' is much more than a Sunday School, and its methods only in a degree are school methods. On the one hand it aims at leading the young to live a Christian life, and grow up into the church-fold; and on the other it stretches deep into secular and social matters, and, in a quiet way, is the instrument of much benevolent work. There is nothing exactly like it in any other city.

It is not a growth of yesterday—it has reached manhood. The coming of age of the Glasgow Foundry Boys was celebrated some time ago. At first it was, in fact as in name, a gathering of real foundry boys, like that started by the late Mr. James Hunter in the hall of a foundry granted by foundry masters. But his effort had died down to feebleness, to be revived when he and Mr. W. P. Hunter, and Mr. Martin, and Mr. Mackeith met on the 21st of November, 1865, to draw up the new scheme that was to succeed so strikingly.

The beginnings were modest enough. A few handbills distributed in the works by the permission of the masters attracted some of the lads together. From the outset the numbers grew. The boys brought their friends, their brothers, and their sisters. Then came a sorting out of the juniors from the seniors, of the boys from the girls; the

institution of the peculiar monitorial system; and the gradual building up of the splendid organization for which Glasgow takes much credit. At first a limit was put to age, or rather size. On the enrolment night each boy was measured to see if he were big enough, and some were sent away disappointed. Their names were taken, and so were particulars as to their family connections. The secretary asked one boy if there were no more at home. 'Yes,' was the reply, 'there's a wee ane no worth countin'.' But the wee anes are thought worth counting now, and the society opens its doors to all.

In the early days the Foundry Boys met in strange places. One class was held in the storeroom of an old mill—'earthen floor, the place cumbered with yarn skips and cop boxes, which, with planks upon them, served for seats, involving at times, to restless members, sudden collapse, the disappearance of half-a-dozen heads, and the upheaval of a dozen heels.' Another in an empty house, the thirteen boys standing against the bare wall; the next meeting having to be held in the lane, owing to the house being taken 'over their heads.' Another in an empty theatre, with a mine below the seats, of which every advantage was taken by the practical joker. Now the unsuitable meeting-places are but few; schoolrooms and halls have been found, among them the City Hall and the Christian Institute, one of the finest of the new buildings of Glasgow.

The object of the society is the religious, educational, and social elevation of the boys and girls of the city and suburbs; but it is, above all things, a religious society, the Sabbath forenoon meetings being the centre towards which all the week work converges; and this paramount position of the religious element is promoted and secured by union with the churches and missions in the different districts, each branch being specially connected with the congregation from which its workers are drawn, and to which a full report of the work of the branch is rendered.

For administrative purposes each branch has its chairman; and the branches are grouped into seventeen sections, each with its superintendent. The management of each

branch is vested in an acting committee composed of two members of the general council, and office-bearers elected from the membership. The general administration of the society is in the hands of eighteen directors, who have the control of the public meetings, finance, the hall accommodation and furniture, and the negotiations with other societies.

The general council exists in order to give each branch a voice in the management of the current work of the four departments; the four departments being the religious, the educational, the social reform, and the provident. Under the council, which is composed of the directors, the office-bearers of each department, and the two members from each branch, comes the control of the publications of the society, of the district meetings of the boys and girls or their parents, of the alterations and additions to the society's work, and the reporting on them to the directors, with whom, as representing the society to the public, and being the only board elected by the whole of the members, rests the final decision on all such matters.

The general council is divided into four departmental committees, each being charged with the management of its own department; and each committee has as office-bearers a general superintendent, sectional superintendents, a secretary and treasurer. The duties of these committees are to institute and promote in each branch the special work of the department, and provide all requisite materials, to tabulate and report the statistics of such work, and to devise or consider improvements on the current work. In addition to the departmental committees there is an extensive committee composed of an office-bearer from each department, who receive and consider all proposals for new branches, or the transfer of old ones.

The opening of a new branch is a very systematic proceeding. The district is regularly surveyed, each street noted, and the number of families ascertained; then the district is divided into portions containing about forty families, and each of these is assigned to a 'monitor.' These monitors are what in the South we should call teachers, their duties being not only to keep the children

orderly in school, but to make friends of them, and take an interest in them on the weekday as well as on the Sunday, visiting the children's homes, ascertaining where help is required, and thus becoming the most important agents in the work of social reform. To each monitor is confided the charge of eight or ten children, all of whose names and addresses must be known, so that absentees can be looked up within a few days of their truancy.

On the morning of the first attack on the stronghold the monitors hold a short prayer-meeting in the hall wherein the society meeting is to be subsequently conducted; and then each is armed with forty handbills, stating plainly the time and place of the forthcoming meeting, and inviting all who do not attend a religious service to be present. They go out to their groups of forty families, and do the best they can to persuade the parents to allow their children to accept the invitation, and come when they are called for next week. Of all that promise, or half promise, they take the name and address—and a Scotch address under such circumstances is a lengthy one, for in the tall whited sepulchres the people live thick as bees, stairway by stairway, flat upon flat, and the address, to be of use, must not only give the number of the street, but the landing, the stair, the door, and the right hand, or left hand, or little behind hand to which you must turn to find it. Next Sunday, just before the meeting, which always takes place at church time, so as to form the habit of obeying the call of the bell, the monitors go out with the lists, and with such recruits as they can secure, return to the hall where the meeting is held. The names are then registered by the secretary, and the first meeting is opened.

As this forenoon meeting is the main feature of the Foundry Boys' organization, let us also obey the bell-call, and, taking one of the largest branches, find our way to the Springbank Hall in Hopehill Road, leading up into Garscube. The chairman of this branch at the time of our visit was Mr. William Martin, the treasurer of the society, a director from the first, having been one of its four founders over twenty years ago.

The service is the same at all the branches; every chair-

man has a programme from head-quarters, and it is his duty to see it carried out in its entirety.

The most noteworthy thing about the Foundry Boys' Society is the thoroughness of its organization; everything is provided for, and printed instructions deal with every detail. The service begins at eleven, but 'fifteen minutes, at least, before the hour of meeting, the doors of the hall should be open, and the boys and girls as they come in receive a warm welcome, and spend the time in singing hymns together.' It is a quarter to eleven when we enter, and the large room is then about half full. The children are just ending a hymn from their own collection, for the society publishes its own 'Scripture Text Book and Hymnal.' Amid a little stir, as the newcomers stop to have the attendance register in the cover of their text book duly stamped, and then find their way to their seats, the voices are heard.

'Little words of kindness, whispered soft and low!
With a thrill of gladness to the heart they go;
Lighting up its darkness with a cheering ray—
Changing gloomy sadness to the light of day.

Little words of kindness, whisperings of love!
God's own hand records them in the world above.
They whose words of pity dry the mourner's tears,
Have the Saviour's blessing through their earthly years.

Little words of kindness seem of little worth—
Yet we cannot buy them with the gold of earth.
Scatter them like sunbeams showing forth His love;
And the Lord of heaven bless you from above!'

The room is arranged so that the boys and girls are separate, and the seniors, consisting of working boys and working girls, are separate from the juniors. The monitors are at alternate ends of the forms, so that in no case are there more than eight scholars without a break. At the back of the platform is a diagram, or rather coloured picture, of the scene of the chief incident in the portion of Scripture appointed to be read for the day—in this case the garden over the brook Cedron, in which the betrayal took place. These landscape diagrams are found of great use in

fixing the attention of the listeners during the Scripture lesson. There is nothing so difficult to make intelligible as descriptions of scenery. Of persons, all seem to be able to have a mental image, but to figure trees, and rocks, and hills, and valleys, is not so easy a matter. The landscape, however rough or glaring it may be, is always looked for and always appreciated.

At eleven o'clock the hall is full, the monitors are in their places with their eight charges to the right or left of them, and the doors are shut. The chairman, after a few words calling the audience to attention, repeats the Lord's Prayer, and in it all join. And then the following programme is gone through:

11 o'clock. The Lord's Prayer.
11.3. Intimation of Week Evening Meetings, &c.
11.7. Missionary Intelligence and Collection.
11.12. Praise.
11.17. Scripture Reading and Explanation.
11.37. Prayer.
11.40. Praise.
11.45. Repetition of Memory Text.
11.50. Address by appointed Speaker.
12.10. Praise.
12.15. Prayer.
12.20. Parting Hymn.
12.22. Dismissal, seat by seat, beginning nearest door.
12.24. Prayer Meeting for Office-Bearers and Monitors:
12.30. Meeting closed.

For the collection, to each monitor is brought a little white wood money-box, duly marked with the number and division, the same box being always used by the same group of eight. The boxes are opened once a month, and the proceeds given to missions and local institutions. The idea is to foster the habit of charity. Individually the collections are trifling, but with such numbers they mount to a goodly sum. Every year the November offerings are taken for the expenses; those of the other months are given beyond the society. But the gifts to the local charities are merely extensions of the society's work; the value comes back in 'lines of admission,' or as we should

call them letters of recommendation to the Homes and Infirmaries.

The praise consists of hymns from the text-book—in which the music is given in the sol-fa notation—and a psalm from the usual version; the voices being accompanied by a harmonium, and directed by the 'leader of praise.' The first prayer is by the chairman, the second by the giver of the address. The portion of Scripture is read by the chairman, and explained and enlarged upon by him with constant reference to the diagram. For every Sabbath in the year the selection is given in the text-book, which also contains the short texts that are to be committed to memory.

The special feature in the service is the address—the arrangements for which are elaborate. Three times a year a list is published; the latest contains the names of 219 gentlemen, who have volunteered to give addresses during the four months, such addresses to be on the text appointed for the day, and not to exceed twenty minutes in delivery. There is a list of the branches, and a calendar, and the 'duties' of the speakers are so arranged that every branch is supplied.

The calendar gives the number of the speaker on the particular day; the numbered list of speakers gives against the name the number of the branch at which he is to speak. On the Monday previous to the Sabbath on which he is to address a meeting, the speaker receives a postcard from the secretary, reminding him of the engagement, and should he not be able to be present, he has to find a substitute. By this arrangement new life is given to the branches; the members see new faces, and are stimulated to thought by different methods, for on no two successive Sundays do they have the same preacher.

At most branches the one hall serves for all the members, and the seats or pews are arranged in the order of Senior Boys, Junior Boys, Junior Girls, Senior Girls, in four columns, or in two columns with Junior Girls and Junior Boys in front, and Senior Girls and Senior Boys behind; but at Hopehill Road the attendance has overflowed the hall, and the juniors are up stairs; in fact, there are rooms

full of boys and girls, some of them hardly able to toddle.

The remarkable thing about these youngsters is the number of them that know how to read. Thanks to the day and night schools of the School Board, the advance in education amongst the Glasgow poor has been very great. In the second year of the Foundry Boys, there were 312 lads, and of these seventy-two were unable to read at all, eighty-eight could only read words of one syllable, and seventy-eight could only read words of two syllables. Things have altered during twenty years. The Society's Educational Department makes a much better return now. In this Educational Department figure School Board Evening Classes, Branch Evening Classes, Mutual Improvement Associations, Literary Societies, Industrial Clubs, Sewing Classes, Cookery Classes, Lantern Exhibitions, Lectures, and a Lending Library, the classes being held from eight to half-past nine o'clock, on two or three nights each week, from October till the end of March. In the Religious Department, besides the forenoon service there are Sabbath Evening Meetings, Evangelistic Missions, a Bible Reading Union, and Tuesday Evening Praise and Prayer Meetings.

The objects of the Social Reform Department are chiefly the promotion of the Temperance cause, and the meeting of the social wants of the boys and girls by providing rational means of recreation during leisure hours. The work has many phases. There are Singing Classes, Orchestral Classes, Drill Classes, Swimming Clubs, Football Clubs, Athletic Clubs, a Rambling Club, Entertainments, Concerts, Soirées, Flower Shows, Excursions, and, above all, the Fair-week trip with its encampment on Loch Fyne; the work in all of which may be imagined, as likewise its influence in helping on the central idea of the society, and finding for the young suitable friends whose example will aid the teaching and help in resisting the downward pull of family tendencies.

What those tendencies are, the Provident Department knows best. It concerns itself with the relief of the sick and destitute, and with the other side of the account in the shape of a Penny Bank, as well as with a Dorcas Society

dealing largely in boots. Owing to the monitors making friends of the children, and visiting them at their homes, many a deserving case for charity is discovered, to be reported in the proper quarter. The society, through its head-quarters at the Christian Institute in Bothwell Street, is in connection with all the leading charitable enterprises of Glasgow, and every branch is the centre of a network of well-doing, the distinguishing feature of which is persistent effort, even among the depths—and to the very lowest depths the operations of the society unofficially extend. Below the careless in matters of improvement are the absolutely destitute, and in dealing with these an offshoot of the society finds full employment. A difficult problem is that which it endeavours to solve in its particular way!

The problem of the poor is ever with us, and our efforts to deal with it meet with such scant success that many fear we are ill-advised. We are told, notwithstanding, that destitution is proportionately less than it used to be. It may be so. There is much in the view that so long as we restrict our studies to the doings of our monarchs, and the records of the battles in the struggle of nation against nation, we skim the past at its best; and that when we explore below the smiling surface of the school-book, and learn how our forefathers lived, the misery of merry England is manifest. It is probably true that the misery has been reduced by a percentage; but there is little comfort in percentages when the bulk increases. Ten in a thousand may be less than two in a hundred, but the average mind sees only the fivefold increase, and refuses to reduce it to its statistical value.

And no friend of his race is likely to be satisfied with this percentage balm. If the misery has been reduced, let us reduce it faster; if the reduction is at the rate of arithmetical progression, let us increase the rate to that of geometrical progression! Whether it be better than it used to be or not, the present state of the poor, physically, mentally, morally, is appalling. It cries out to us; it is a scandal to us. What is to be done?

Mr. Mackeith is trying a solution by means of free meals. Free meals are not peculiar to Glasgow; but they may have

different developments. Let us go to this Sunday afternoon dinner and judge for ourselves. There is not much difficulty in finding the way to that thickly-populated neighbourhood into which the railway to St. Enoch's lets so much beneficent daylight. The main road is clean and clear enough, but the wynds and closes on either hand teem with the dirty, the callous, and the miserable. Past the Tron kirk, we turn into the Saltmarket, and are but a few steps from the Green, when we reach the handsome new hall in James Morrison Street. There is a crowd at the doors and in the road; but this we avoid as we make our way at once to the kitchen.

Around us are preparations for feeding on a large scale, and all is quiet and orderly. Three huge cauldrons there are, each holding about ninety gallons, and full of simmering rice and milk. A table is pushed close to them, and at one end of it is a well-cleaned wooden washing tub. Some half dozen young fellows are bringing in scores of quart mugs, and stacking them round the tub.

The lid of the cauldron is taken off, and one of the lads dips a huge ladle as big as a hand bowl into the thin white pudding and transfers it steaming to the tub. At the same time two others seize the mugs one in each hand, and dip them into the tub and fill them. Two others seize the hot filled mugs and lay them side by side in deep wooden waggons. Twenty-four mugs go to a layer. When the layer is complete, another lad standing ready with a sheaf of spoons drops one into each mug with such dexterity that there is no pause in the packing. The work goes on like clockwork; the ladling from the copper into the tub, the dipping of the mugs, the stacking in layers, four layers in each waggon. The full waggon is wheeled away and another is ready by its side, and soon the three cauldrons are empty, and a dozen waggons are full. On the top of each waggon a thin iron cover is placed, and on this is put a large basket of bread, a piece of bread for each mug. The loaded waggons all stand in a row ready to be run into the meeting.

The hall is under repair to-day, and the children are in the so-called tent, whose wooden roof and silent earthen

floor give every help to the sound of speech and song. The area is crowded with seated children. As seen from the platform, the girls are to the left, the boys to the right. There are three columns of forms; the centre is double the width of the wings. These long forms have each eight boys and eight girls, and at each of their ends is a 'monitor.' At the end of each other form is also a monitor, so that the monitors line the gangways, with small classes of eight to the right or left of them.

As we enter the children are singing—

'Come to the Saviour, make no delay:
Here in His Word He has shown us the way;
Here, in our midst, He is standing to-day,
Tenderly saying, "Come."

"Suffer the children!" Oh, hear His voice!
Let every heart leap forth and rejoice;
And let us freely make Him our choice:
Do not delay, but come.'

Timid and silvery sound the girls' voices as they softly sing the third verse—

'Think once again, He's with us to-day;
Heed now His blessed command and obey;
Hear now His accents tenderly say,
"Will you, my children, come?"'

And with their full strength the boys join in, with just a touch of defiance in their tone; and the chorus swings out with vigour—

'Joyful, joyful, will the meeting be,
When from sin our hearts are pure and free,
And we shall gather, Saviour, with Thee,
In our eternal home.'

The sight is an affecting one, especially to those who see it for the first time. There is always a spell in the voice of numbers, be it in panic or praise, in joy or sorrow; but beyond this there is here something purer, deeper, more precious. The heart thrills in sympathy with the little people so eagerly expectant and so determined to sing their

best to please their leader and enjoy themselves in his way; and the thought comes to us that in but a little our children differ from these, and may at any time become as they are. How have these come to this? What can be done to lift them from it? The book of poverty lies open; the faces are its pages. Many there are sickly and weak; some even with the hollow cheek and bluish bones showing through the thin flesh, and telling the bitter tale of starvation. Some there are with delicate features refined by suffering; a few are coarse and aggressive, telling unmistakably that the failure cannot be entirely charged to others. Many would be beautiful were it not for the shifty look of the outcast. Many have good faces, pure and true, such are safe to keep to the right road if only the chance be given them. A few are in rags, openly and boastingly; but most have their shawls or jackets held or pinned tight, so as to make the best show they can. Bare-headed are most of the girls, and bare-footed are many of them, though not from choice, for the crippled toes tell of ill-fitting boots. There sit the children, a thousand and one odd possibilities, samples of thousands more amongst us. What are you going to do with them? Are they to be your friends or your enemies? If you cannot lift them all, how are you to sift them?

Now they are thinking but of the moment, carried away by the music of their own voices, with eyes keenly watching Mr. Mackeith as he times and leads them; and when the hymn ends, listen as the voices follow his to the Lord's Prayer, 'every eye closed, every head bowed.' It is not often that the petitions so strike home.

Then there is another hymn, sung with as much vigour as the last; but in the middle the boys get ahead, and have to be pulled up. Another start is made, and all goes smoothly; then, for a few minutes, Mr. Mackeith talks to his little folks of their last Sabbath lesson, which they are supposed to have remembered, and cheerily come the answers back from dozens at a time, though most of the correct ones hail from the girls. Sometimes there are over 2,000 children—a large class to manage; and yet it is done in a style that is truly masterly. For an example

of unfailing tact and quiet power, let the student go to the United Evangelistic Hall, James Morrison Street, on a Sabbath afternoon, and see how Mr. Mackeith, without apparent effort, keeps in hand the roughest of the waifs and strays of Glasgow.

After the address, which is neither long nor dull, another hymn is sung, a one-verse hymn suiting well the little voices in words and air.

'Two little eyes to look to God,
Two little ears to hear His Word,
Two little feet to run in His way,
Two little hands at His work every day;
One little tongue to speak His truth,
One little heart to trust Him in youth.
Take them, my Lord, and let them be
Always obedient and true to Thee.'

And while this is being sung each monitor has an apron given her, which she unrolls and ties on; and the waggons appear from the back, and are wheeled up each gangway, six in Indian file, one behind the other, for the girls; six, in a similar way, for the boys. As they advance many are the wistful glances from the children. Then grace is said by all, short but fervid, and evidently meant: and the monitors take into their aprons a piece of bread for each of their charges, the covers are removed, and the mugs passed along. So good is the organization that in half a minute from the saying of the grace the waggons are empty, and every child in the hall is deep in what in many cases is the only sure meal of the week. Most of them eat ravenously; but one little girl in front of us has a sick brother on her knee, and though she looks hungry enough herself, she feeds him first and leaves her share untouched for a while. And there are others like her. Some of the girls have brought babies in arms with them; and such of these as have become restive have been taken out and had their meal at once. It is difficult to guess the ages; poverty makes some children so small for age, while others it makes look older than they really are; but few of the children can be more than twelve.

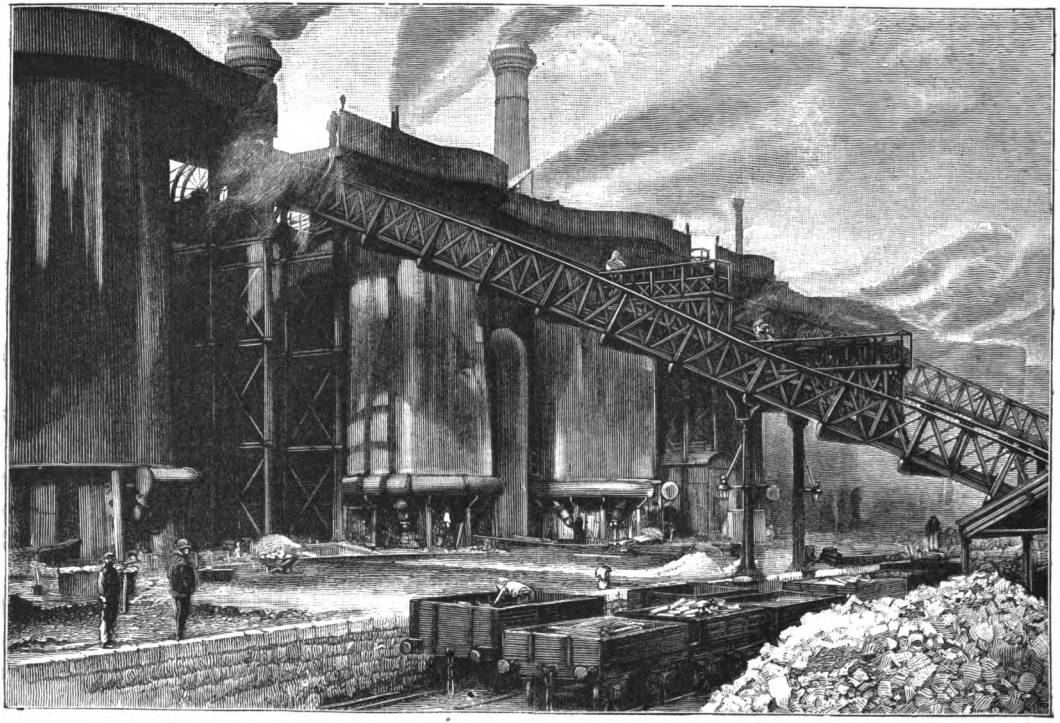
Quickly the mugs are emptied and replaced in the waggons. At the end of a quarter of an hour a hymn is sung, during which the waggons are drawn back. Then comes a short prayer, and at three o'clock precisely, an hour from the commencement, the dismissal takes place. Seat by seat from the rear the children leave, the monitors stepping into the empty seat behind and sitting down with any of the children who wish to remain for conversation. And some do remain; often some who have been driven out to starve, and will never see home again; and often boys and girls who have run away from home in search of liberty and have come here starving, asking to be sent back. To-day, as if to complete the picture, there is a 'prisoner' brought to Mr. Mackeith, a boy who has been detained for fighting during the meal. A typical Arab he crouches at the foot of the platform wondering what is going to happen to him; a good-looking ne'er-do-well if there ever was one; gipsy-like in face, with brilliant dark eyes, restless and alert in search for a means of escape; bare-headed, bare-footed; in rags, with a bit of a shirt torn open down the chest; an untamed animal with the makings in him of a handsome man. 'Fighting, were you?' No answer. 'What good did it do you?' No answer. 'Will you fight if you come here again?' 'No,' says the culprit, looking at the ground. 'Then you can come again. Go!' The boy is off like a flash; not till he is out of the tent does he stand upright.

In the winter the attendance is much larger than it has been to-day. Then broth or soup is given instead of rice and milk, though rice and milk is the most popular food. To-day, too, we are out in the tent. To see the service complete we should have been in the great hall, and heard the blackboard lesson. An interesting educational feature is this, here originated, and hence adapted freely elsewhere. On the platform is a huge map of Palestine. The map begins with the tracing of the coast line. Then Sabbath after Sabbath Mr. Mackeith builds it up before the eyes of his audience. As he tells the story of the Saviour he marks on the map the towns and the villages, and the hills and rivers. The children see the map

grow before their eyes, and remember all its steps. The lesson for the day is but a short one, and few additions are made to the map. But the map is not the only means adopted for securing the attention of the children. Each lesson is illustrated by a drawing on a sheet of glass, eight feet square, in coloured crayons, done by Mr. David Pratt, sometimes before the meeting, sometimes in the presence of the children. The map gives the locality, the diagram pictures the scene, the lecturer tells the story, and the children with their memories aided in this way rarely forget.

The good all these agencies are specially doing no one can tell. It is impossible to apportion the relative values of simultaneous moral influence. One thing is certain, the institutions in Glasgow for the prevention and repression of juvenile delinquency are all in a languishing condition. 'The directors of these legal and restraining institutions,' reports the City Chamberlain, 'rejoice that their labours are yearly lessening, notwithstanding they feel themselves placed for the time, and from a purely financial point of view, in an unfavourable position, having to maintain establishments which had to be designed to meet the approval of the Secretary of State, and now happily becoming emptied because of the active voluntary benevolence growing more and more potent year by year. In truth, it would appear that the good old philosophy has come back to us, and is not only preached but largely practised, that inculcates in the well-to-do personal interest in the poor, and those out of the way, and very specially an interest in the young, whose surroundings are more likely to give to them a wrong than a right start in life.'

And now southward ho! for the head-quarters of hæmatite, for a day among the ironworkers.



THE BLAST FURNACES AT BARROW.

CHAPTER V.

HÆMATITE.

THE distant ring and clang of iron; two streams of cloud—one white and light, the other grey and ponderous—racing at different speeds across the watery moon. A range of wall and shed, with its hard, unbroken shadow thrown in sharp outline along the middle of the road. Against a momentary rift of blackness, or feathery veil, or sombre cumulus, a flood of sparks, like gold and silver rain, bursts up, while swords of vivid light are brandished to and fro on to the hurrying clouds; the clouds glow only in the blades of flame; the glare is red, and violet, and lemon-yellow; the colour-bands shorten and stretch, and glow and fade, with the flash of the swords and the drift of the mist and steam that float from the dark foreground to join the cloud-seas in the sky. A crow, and a whistle, and a roar, and more flashing and outbursting of fiery atoms, and more ringing and clanging, now near, now more distant. The moon is hidden for a minute, and all the light comes from behind the wall, and the shadow in the road is blurred. Then the moon appears again from behind the curtain to soften the fire colours with its milky, silvery beams, and deepen the main shadows; and we seem again to be in a spirit land, where certainly the weary are not at rest.

All night long the work goes on, and the sparks fly, and the flame-swords flash; and in the daytime there is no ceasing, although the sun overpowers the lights of the night and robs the scene of all its beauty. He who would see

Melrose aright should see it by the pale moonlight; he who would see at their best the red ruins of the abbey in the Vale of Deadly Nightshade should see them under similar circumstances; and so should he who would see the scene of strenuous work of which the good Furness monks never dreamt. A strange place is Barrow on a rainy, windy night! There are 250 acres of it, bright and busy as in the daytime; beyond them is the silent sea; before them a town in darkness, with only a few gas-lamps, and scarcely a light in a window; wide streets, with not a dozen persons in a mile of them; and in the middle of the streets a tram-line, along which glides at frequent intervals a spectral steam-car, boasting not a solitary passenger.

The empty tram-car is a type of the Barrow-in-Furness of to-day. Everywhere are the facilities for doing a flourishing trade — when it comes. It is a town of extreme newness, a model 'emporium,' the most colonial of our towns, planned out in parallelograms, with no narrow lanes or short cuts, the journey across in any direction being a painful beating to windward along any two sides of a series of rectangles. There is a broad road of approach lined with trees, and spacious streets and well-built houses, all of pleasing monotony; and arrangements, sanitary and otherwise, all of the latest. There are public buildings of the noblest—a grand Town Hall, with dominating tower; a splendid Free Library, with one of the best newsrooms in the kingdom; a Working Man's Institute; a Science and Art School, for technical education; churches, board schools, baths, markets, hospitals, all new, and specially built for their purposes; shipbuilding works and steel works, and other works for the men; flax and jute works for the women; enormous docks, all of them designed with a view to the future, and all of them too big for the present.

The history of Barrow is a short one. Two hundred years ago George Fox, the founder of the Society of Friends, came to the seashore hereabouts a fortnight after his ill-treatment in 'the steeple-house at Ulverston,' and nearly met his death from the villagers of Cocken. He converted the Lancasters, and retired to Ulverston to marry Widow

Fell and become the owner of Swarthmoor Hall. Cocken then vanished into darkness to be speedily merged into Barrow when the awakening came. In 1845 there were seventeen houses in Barrow. In 1861 Dalton and Barrow united boasted a population of 9,152. In 1871, when Barrow for the first time was thought worthy to stand alone, it had a population of 18,774; in 1881 the numbers had increased to 47,000. Birkenhead and Middlesborough are the only two English towns that have equalled its rate of increase.

In the days of the Bruce, when the Scots came southward in chase of Edward II., Holinshed tells us that they penetrated into Furness and carried off the iron with the greatest joy, 'preferring it to any other plunder.' The rich store of metal must thus have been known and worked in those days, and, indeed, the remains of the old bloomeries —for our forefathers worked in the Catalan way—are still found among the Furness fells. One case is on record of an old malleable iron hammer weighing 350 lbs. being found in one of these ruins, and carried off and put to work again! The mineral wealth of the country appears in some places on its surface, and could not well be hid. Even the grey monks, who with the patronage of Stephen, Earl of Moreton, afterwards King of England, moved under Abbot Ewan from Amounderness to found the great house in the Nightshade Vale, must have known that they had not come into a poor land; and the abbots who followed, and who in the strange record are only thought worthy of mention when they exceeded a ten years' reign, must have owed much to the district smiths in the abbey's advance to be the second wealthiest in these islands. But none of the early pits or foundries seem to have existed between the abbey and the sea.

The chief sources of supply for the existing ironworks are at Stank and Park. The Stank mine, the deepest in Furness, was discovered in a fruitless bore for coal. The Park mine was found in 1839, when Mr. Schneider bored and bored, until, with but a covering of gravel on it, he struck the hæmatite close to the surface. That was a great find for Furness. Soon its ore came to be shipped coast-

wise and abroad; and as a port for its shipment the 'Liverpool of Northern Lancashire' began. In course of time Messrs. Schneider and Hannay decided to smelt the ore on the spot, and the first three furnaces were built, which were first charged on October 17th, 1859. Five years after that the new company was formed for the manufacture of Bessemer steel, and on the 23rd of May, in the year following, the first steel was made. The first chairman of the board of directors was the Duke of Devonshire, the owner of much land in the district. He was succeeded by his son, the Marquis of Hartington, who still holds the post. The works grew—they have grown to some degree Channelwards by the deposit of their own slag—and they now cover 250 acres. They give employment to 5,000 men and boys, and they turn out in a year 300,000 tons of pig-iron and 140,000 tons of steel.

We need not dwell on matters mineralogical, but must say something to make our subject clear. The local ore is red hæmatite, an anhydrous ferric oxide, singularly free from those banes of the ironmaster—sulphur and phosphorus. Over 1,000,000 tons a year are raised, and smelted or exported, from the Permian and Carboniferous rocks of North Lancashire and West Cumberland, the deposits being richest at the junction of the slate and limestone. The ore is a dense red earth, with sixty-six per cent. of iron. The Forest of Dean iron comes from brown hæmatite, or hydrated ferric oxide, with sixty-three per cent. of iron; that of the Northampton pits is a brown ore, with thirty-nine per cent. of iron. The Somersetshire iron comes from a spathic or crystallized ore, or ferrous carbonate, with thirty-five per cent. of iron. The Low Moor iron comes from the clay ironstone of the coal measures, and the ore is a carbonate, and has twenty-nine per cent. of iron; the Staffordshire ore comes from the same formation, and has thirty-six per cent. of iron; the Monmouthshire Black Band has also thirty-six per cent. of iron. The Cleveland ore is also a carbonate, but it is of Oolitic age, and has thirty-four per cent. of iron. The hæmatite is thus the richest; and, unlike the carbonate ores, it requires no roasting, so that it has not to pass through a kiln to be prepared for the

furnace. Let us follow the red ore into the works, and see what becomes of it; let us discover the origin of the volcanic outbursts and swords of flame that make the night clouds glow. On the chart the mariner in the Irish Sea is directed to note the furnaces at Barrow; let us make their closer acquaintance. We could not have a better example for our sketch of ironworkers at work.

In width the works of the Barrow Hæmatite Iron and Steel Company cannot be much less than a quarter of a mile. There are three main rows of buildings. To the east are the blast-furnaces; to the west are the steel works; in the centre is the lower row of mixing sheds. The area is covered with a network of railways, and the trucks bring in the red ore direct from the pit mouth to the mixing floor. As we run in, the furnaces tower up to the left, tall and bulky, thirteen out of fourteen of them in blast. Behind them are the stoves and engine-rooms, with the Channel beyond. From the top of every two furnaces there starts an inclined plane, which at about half a right angle crosses the railway lines down into the roof of the mixing shed. In the shed the red ore is weighed out with certain proportions of limestone from Stainton Quarry, and coke from Darlington, in order that it may have flux and fuel. The fuel used for smelting is not the same all the world over. In some places charcoal is used; in America we have iron smelted by coal-tar, by raw petroleum, or the lighter benzoline, and even by natural gas, turned direct from the earth into the furnaces. Here every thirty-five hundredweights of ore has twenty-one hundredweights of coke and eight and a half hundredweights of limestone, making a total load of three tons four and a half hundredweights, which is stowed on a peculiar barrow that fits the inclined plane, so as to run up and down with its floor horizontal. The yield of metal averages fifty-seven per cent.; and thus for every ton of coke sent up a ton of pig-iron is expected to be run. As soon as the load is ready, a man takes his station on the barrow, and at a given signal away he goes up the slope and through the roof—higher, higher in the air across the railway lines to the platform at the furnace-top. Halfway up he meets a mate with an empty barrow coming down;

and when he, in his turn, comes down with his empty barrow, he will in like manner pass the full charge going up, the lift being worked on the usual principle of colliery winding-gear.

The furnace is over sixty feet high, and is seven yards in diameter; it has an internal firebrick lining eighteen inches in thickness, between which and a circle of brick is a space filled with sand, the whole being enclosed in an outer casing of iron plates riveted together. At the top is an arrangement by which the gases which were allowed to flare to waste in times gone by, are collected and led away about the works, to be used in driving the boilers; and these give all the force that is required to provide steam for the numerous blowing and winding engines. It is not from the blast-furnaces that the rays on the night clouds come. At the top is also the cup and cone arrangement by which the furnace is fed, the charge being tipped all round the cone, so as to distribute it equally.

When the furnace was 'blown in,' a quantity of wood was laid on the hearth, then a mass of coke was placed on the kindling wood, on that were placed alternate layers of coke and limestone, and then a little ore. As soon as it was a third full the wood was lighted, and when it was fairly in combustion the furnace was filled to the top with ore and fuel and flux, and the blowing commenced very gently, the blast and the amount of ore being gradually increased during a few days until the full blast and burden were attained. Since then, night and day, without a pause, the barrows have journeyed up the slope with their load from the mixing shed and tipped in tons upon tons of ore and coke and limestone, to feed the never-ceasing fire.

What the temperature of a blast-furnace is it has been sought to discover by the use of alloys of known melting-points placed at different levels within it. The heat varies with the height; at the top it was found to be 320° C., at the bottom 1450° C. Just below the top, where reduction takes place by the contact with the carbonic oxide, the fire is a dull red; the red becomes brighter lower down, and the limestone is decomposed; lower still, it is a full red where the absorption of carbon probably goes on; below that, where the furnace is at its broadest, is a zone

of brighter red, where the sulphur and similar elements, if any, are reduced from the charge, and combine with the pig-iron; as the furnace narrows—'in the boshes,' to use the technical term—the heat reaches bright-redness, and the descending charge of spongy metal and slag-formers undergoes thorough fusion; and in the crucible the heat reaches whiteness, the fused metal and slag separate—the slag being drawn off above the level of the molten metal by a channel-way into the slag-waggons, and the metal being run off at the lowest point on to the pig-bed.

From one of the furnaces we see the slag removed, run into railway trucks, and taken by an engine about half a mile up the works, where it is shot out on to the bank and utilized to increase the area of the company's property at the expense of the seashore. From another we see the metal tapped. There is a narrow stream of vivid brightness, which in a few yards dulls down to ever darker red as it flows like treacle into a series of furrows arranged as regularly as the Barrow streets, with the necessary main thoroughfares, the top ends of each row communicating with a common channel, along which the metal runs to supply the furrows that communicate with it. This common channel is the 'sow,' the furrows fed from it are the pigs; when the litter has been supplied the man in charge cuts off the communication with a slip of clay, and the litter just above is then attended to, and thus the cast takes place quickly and regularly, and soon the D-shaped furrows are full of iron 'pigs,' each weighing as nearly as possible a hundredweight, and going to make up the pig-bed load of five-and-twenty tons. On another pig-bed we see the next operation in progress; the men are with sledge-hammers breaking apart the pigs from the sows, and knocking them into separate existence. A very warm job this seems to be, for were the men to wait till the iron was cold the force required to break up the massive gridiron would be tremendous. They have to strike while the iron is hot—while twenty-five tons of it are hot!

Between the furnaces and the Walney Channel—the short strait that cuts off Walney Island from the mainland—is the winding engine, with its ropes and big wheel.

On the wall is the regulation tell-tale; on the wheel is the usual chalk-mark, without which no engineman would be comfortable. A gong sounds; the engine starts; the tell-tale moves as the barrows on the incline run swiftly up or down. As the tell-tale reaches the end of its tether the engine is slowed, the chalk-mark on the wheel is watched, and when it is opposite the appointed place the wheel stops dead. The empty barrow has reached the mixing floor; the full one is on the platform at the furnace-head.

By the side of the winding engine is the long row of blowing engines, on grasshopper and other principles, which serve as lungs to the colossal blowpipes that help up the furnace heat so wondrously. Before Neilson applied the hot blast to the Clyde Ironworks in 1828, the air driven into the smelting-hearth was cold, now it is always heated by being passed through chambers of fire-brick before it enters the flames. Between the row of engine-houses and the furnaces are the stoves through which the blast is passed, all of which are heated by the waste gases from the furnace-tops. Some are on Cowper's plan, some on that of Gjers; but all work the air up to a temperature of 900° Fahrenheit before they part with it. To every furnace are six twyers, or mouthpieces, with four-inch nozzles, cooled by constantly flowing water; and these are the lips of the ardent Æolus, through which is blown the never-lulling simoom of the smelter.

But let us return for a moment to our pigs, whose rent-paying powers are unfortunately in these hard times as feeble as those of their Irish namesakes. Not so very long ago the iron required for Bessemer steel making was cast into pigs, which were taken away from the litter and re-melted before their conversion. Now the pig stage is omitted, and the fluid metal drawn off from the pig-bed down an iron spout lined with sand, and poured into a massive ladle swung in a strange-looking railway-truck. Such a ladle is worth following; it contains eight tons of liquid iron. As we look across the rails to the steel works to which it is bound, a black cloud obscures the sky, and, in the momentary loss of light, a flash of flame shoots up

from the roof, and close by is a burst of glittering rain. Evidently the cause of the brilliant illumination of the night is yet to be found, and, with the ladle, we are on the track. By a somewhat circuitous route, passing a weighing-machine on its way, the ladle enters the steel works.

At the northern end of the three wide sheds, which are 735 feet long, are the Bessemer converters and Siemens furnaces, for both processes are here extensively worked; at the southern end are the hammers and the rolling-mills, from which we can hear the steel rails clanging as they fall on to the guides that run them out into the air. In the bright light and dark shadow we make out four casting-pits, with two converters at the side of each; huge short-necked retorts, of familiar form now, lined thick with refractory ganister from Sheffield or elsewhere, riddled with holes at the bottom, to admit the blast that passes down into the twyers through one of the trunnions. In the centre of the pit is a hydraulic ram, on which is the platform carrying the ladle that is to receive the steel when duly cooked, and pour it out into the circle of ingot-moulds that stand ready below. The whole of the machinery is hydraulic, and we take our stand on a sort of bridge, from which the man in charge, by turning different wheels, gives the ponderous apparatus almost human facility of movement.

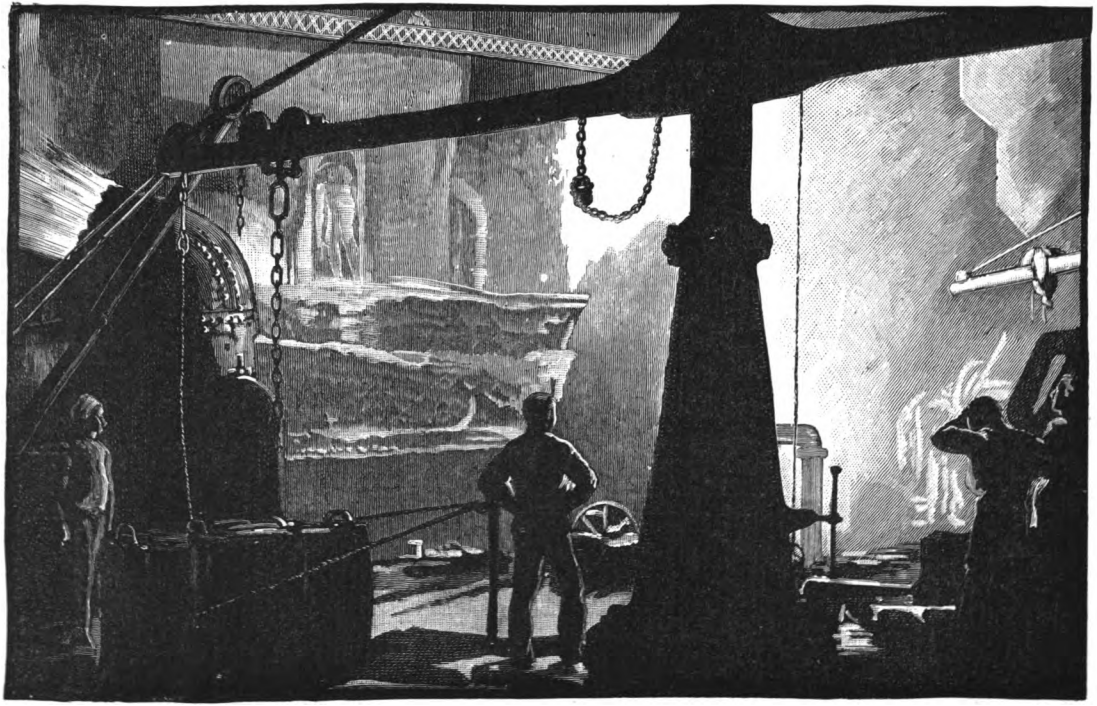
The converter, with its mouth turned down, is receiving the charge that the travelling-ladle has brought in on to a higher platform from the blast-furnace. In the vessel's horizontal position its flat, perforated bottom is vertical; and, owing to its curved sides, the fluid metal is in a sort of bowl, and does not rise to the level of the twyers. When the charge is all in, the blast is turned full on, and at the same time the converter rises upright. Instantly there is a shower of sparks from the open mouth, as the fluid metal is danced and dandled on the storm that is driven in through the twyers. Were it to sink into the holes the consequences would be disastrous, but it has no chance to do so. The pressure of the air is greater than the weight of the iron, and keeps the inlets clear. The flame goes roaring wildly aloft under the hood, up the flue, into

the air. Every now and then a sheaf of sparks is thrown out and danced sky high. As the minutes pass the flame brightens; and how bright it gets can be judged from our illustration, in which Mr. C. P. Richards has with great skill photographed the Bessemer pit by the light from the converter. Longer and longer, fuller and fuller, brighter and brighter it glows; the sparks get more irregular, and change in hue, or seem to change, for the eyes are dazzled. The flame turns from vivid white to pale amethyst, and as it takes the amethystine tinge it thins and dies.

Then a gong is struck as a warning, the vessel turns over on its back with a big discharge of sparks, and a pick-me-up seems to be administered, that it may make one effort more. And the effort is a startling one, for from the mouth there leaps a long, faintly-bluish, lambent flame, that tells the cook his work has prospered. A turn of a wheel, and the converter leans far enough back to pour its water-like contents into the heated ladle in the pit. As the pour is ended we move round so as to look into the vessel, and we can see the white-hot bottom freckled with the twyer-ends, every tube being visible. Mould after mould is filled from the ladle, as it moves round the pit in obedience to a wheel on the bridge, and soon the liquid iron we followed half an hour ago from the blast-furnaces will be ingots of steel.

The principle of the process is not difficult to understand. The pick me-up we saw administered was a small dose of spiegeleisen from a furnace close by. Spiegeleisen is pig-iron's most highly carburized and crystalline form; air is blown through the liquid charge to burn out the carbon, and the spiegeleisen is added to produce a metal of any required degree of carbonization.

When George the Second was king, the best steel used in this country was made by the Hindoos, and cost £10,000 a ton. In 1740, Huntsman, a Doncaster clockmaker, driven nearly wild by the springs of local steel he was forced to use in his trade, took up his abode at Handsworth, near Sheffield, and proceeded to experiment on making steel for himself. After long trial and failure, he succeeded in producing steel as good as that made by the



THE BESSEMER PIT AS PHOTOGRAPHED BY THE LIGHT FROM THE CONVERTER.

Hindoos, and at a hundredth of its cost; and for a hundred years Huntsman's method was the only one in use in this country. In 1770 he came to Attercliffe and opened works in which his men were sworn to secrecy. Despite the local opposition, the fame of his steel spread far and wide, and the Sheffield manufacturers endeavoured in vain by bribery and stratagem to rob him of his secret. They eventually attained their end. One bitter winter's night a shivering beggar knocked at the gate of Huntsman's works and asked for shelter; the kind-hearted workmen took him in out of the snow and gave him a corner where he could sleep. The beggar was a spy, an ironfounder at Greenside, who covered his face with his hands, and while the workmen thought he was asleep watched their work through his fingers. In the centre of a peculiar furnace were placed two chests, or troughs, heated all round by holes in the flues. The dust of charcoal made from hard wood was sifted into these till it was two inches deep; bars of iron were then put in upon their narrow edges half an inch apart. Powdered charcoal was then sifted in, then another layer of bars was arranged, then more charcoal sifted, and so on until the chests were filled to within six inches of their tops, and held from eight to twelve tons of bar-iron. On the top was placed a mixture of damp charcoal, or soot, and sand, so as to keep out the air, and the chest being closed in, it was subjected to the action of fire for a few days until the bars had absorbed the desired amount of carbon. This was 'the cementation process' which the spy saw, and which a few months afterwards he introduced at Greenside, and thus gave Huntsman's secret to the world.

Sometimes two or three cementations were necessary. When the process was completed the surface of the bars was covered with blisters, whence the term of blistered steel. To be fit for forging it had to be made into shear steel. The bar was broken into lengths of a foot and a half, four or more of which were bound up in a bundle by a ring, and in their faggot-form raised to welding-heat and hammered into the solid shear steel rods at the rate of 300 strokes a minute. As the rod formed, the heat

from the furnace cooled away, but the swift blows of the hammer would revive the redness and even set the metal on fire. To make cast steel the bars were broken into little bits and placed in crucibles holding about thirty pounds each; powdered charcoal was dusted in, and the crucibles were well covered; and in four hours the metal was fluid and ready to be poured into moulds, much as bronze is melted and poured at the Mint.

We have seen that the Barrow converters are now at work where Friend Lancaster lay on George Fox and shielded him from the attacks of Mrs. Lancaster, who considered that he had bewitched him. It is equally well worth noting that the first Bessemer converter was built and tried in the house of old Richard Baxter, of the *Saint's Everlasting Rest.* In that old house in St. Pancras, in 1856, did Henry Bessemer build the kettle that was to change the iron trade of the world. It was three feet through and four feet high, and held seven hundredweight of iron, and it was lined with fireclay. Connected with it was a small engine, to force streams of air under high pressure through its bottom.

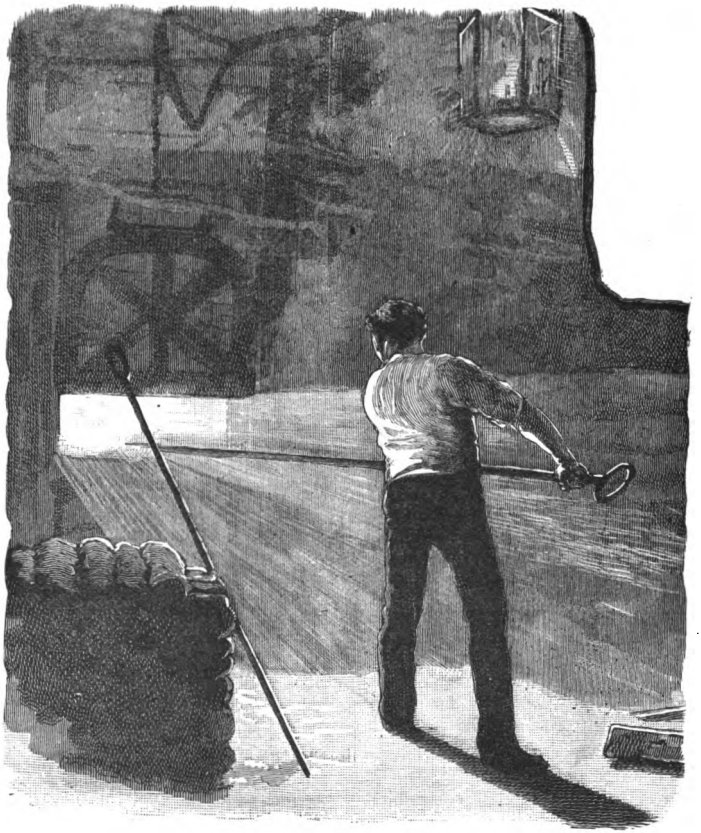
'A cast iron plate,' says Mr. Jeans, 'one of those lids which commonly cover the coalholes in the pavement, was hung over the converter; and, all being ready, the stoker in some bewilderment poured in the metal. Instantly out came a volcanic eruption of such dazzling coruscations as had never been seen before. The dangling pot-lid dissolved in the gleaming volume of flame, and the chain by which it hung grew red and then white as the various stages of the process were unfolded to the gaze of the wondering spectators. The air-cock to regulate the blast was beside the converting vessel, and no one dared to go near it, much less to deliberately shut it. In this dilemma, however, they were soon relieved by finding that the process of decarbonization or combustion had expended all its fury; and most wonderful of all, the result was steel!'

What is steel? What is iron? One so overlaps the other now that it is not easy to say. Steel is a mixture of iron and carbon, but pure iron is commercially unknown. All cast iron has carbon in it, and so has all malleable

iron. As steel approaches to pig-iron on the one hand, or malleable iron on the other, in physical characteristics, so does it approach in chemical composition. In mild steel the carbon may perhaps not exceed a tenth per cent., while malleable iron may contain a quarter per cent.; and yet the steel can be welded almost as easily, and worked under the hammer at nearly the same temperature as the iron. And a similar state of things exists at the other end of the scale. Steel, in fact, is taking the place of iron at both ends. The Iron Age has passed; this is the Age of Steel. We shall see immediately that even our 'tin' pots and kettles are now made of steel! As Sir William Siemens said, in 1869, 'a great revolution of our constructive art has been prepared by the production in large quantities, and at a moderate cost, of a material of more than twice the strength of iron, which instead of being fibrous, has its full strength in every direction, and which can be modulated to every degree of ductility, approaching the hardness of the diamond on the one hand, and the proverbial toughness of leather on the other.'

On the development of the Bessemer process we need not dwell. At first it was capricious in its results, succeeding sometimes, failing at others, but the cause was found in the differing qualities of the ores; and since the discovery of the secret of the spiegeleisen all has gone well. Even the spathic and other ores of Cleveland and the Continent, for a long time out of its range, can now be satisfactorily treated by the 'basic' process of Thomas and Gilchrist, in which the ganister lining of the converter is replaced by bricks of magnesian limestone. A difficulty in the casting of large steel ingots, where the metal often rises and becomes honeycombed, was met, it may here be as well to say, in the invention of the astonishing squeezing process of Sir Joseph Whitworth, in which the liquid metal is run into a lined mould and subjected to a pressure of many tons on the square inch, the ingot shortening an inch and a half in every foot, while jets of gas shoot spitefully from the vents and fine metallic rain squirts out over all. But it is time we went to the Siemens furnaces where the mild steel is being made.

A few thin beams of intense vividness shoot out from the doors. One of the furnaces is being charged. The sliding



THE MAKING OF MILD STEEL.

door is up and we look into the glowing oven. Pigs from the blast furnaces are being shifted about and placed in position

like loaves, with a baker's peel. The pigs are to form the bath in which wrought iron and steel scrap is to be melted. Great is the glare, but nothing like that from the furnace on the other side, in which the bath is molten and the process in full swing. There the intensity of the light is such that we look at it through coloured glass, so as not to injure our eyes. The heat is terrific. We can see the wide lake of liquid metal simmering and spurting like porridge; and when a few new lumps are thrown in to show the effect they are thrown up and jumped about and cracked and made away with by the mass in a most exciting manner. 'It is boiling,' we say. But the master-cook is indignant. It is not what he calls boiling. Boiling is a technical expression referable to a future state, to which the present heat is, we are told, but child's play. Practically the limit of heat is the point at which the materials of the furnace would themselves begin to melt; theoretically it is 4,500° Fahrenheit, when hydrogen and oxygen, the two gases that necessarily combine in combustion, become dissociated.

But a word should be said as to the furnace itself. It has three essential parts—gas producers, regenerators, and the melting-chamber. The four regenerators are below the furnace, and are elaborate chequerworks of firebrick into which gas and air are introduced and passed on through them to be ignited in the melting-chamber. Thence the current descends to the other regenerators and heats them in such a way, that while the uppermost chequerwork is heated to nearly the furnace temperature, the lower parts are heated to a less and less degree, and the products of combustion part with nearly all their heat before they escape into the chimney. In a short time the current is reversed, so that the cold air and gas ascend through the previously heated chambers, take up the heat there left, and again enter into combustion at the entrance to the furnace at nearly the same temperature at which the products of combustion left it. The melting temperature is thus enormously reinforced, and after combustion the products again return through the other two regenerators and raise their temperature considerably on their passage

through the firebrick maze. Thus the game goes on, alternating the current so that the bricks get hotter and hotter, and send it hotter to the furnace at each reversal.

But we have been melting long enough. We have made our steel. What is done with it? Sometimes it goes away in ingot form. Oftenest it is dealt with further, and leaves the works as rail, or bar, or plate. Passing through the forge space with its steam-hammers, working on pyramidal anvils cast in position and inverted, let us follow an ingot that has just been extracted from a re-heating furnace. It is run on a trolly to a powerful rolling-mill with three rows of rollers whose action is never reversed. By the centre and lower roller it is gripped and taken through on to a platform on the other side worked by hydraulic. The instant the end is past the rollers the platform rises, and the flattened ingot is gripped by the upper edge of the centre roller, and passed through to the other side, where a corresponding platform is ready for it. Instantly the platform drops, so as to present the now much lengthened and flattened mass to the lower roller; and so, in and out, and falling and rising, the ingot is run through again and again, every time passing through a different grip, and every time getting thinner and longer, until at last it emerges on to the travelling guides, and runs out into the open air as a 'tin bar,' ready for South Wales, and eventual conversion into kettles and canisters. Since Henry Cort invented it, in 1783, a year before he invented the puddling furnace, the rolling-mill has not altered much. Set up and working, it does not compare favourably with the steam-hammer; but when it is in pieces and under repair, the massiveness of its parts makes it look the more powerful tool of the two. In a shed, across another group of railway lines, we visit a store of these mighty rollers. Here they are in dozens, big as the guns at the Portsmouth gun wharf, laid up in heaps, some of them on the lathes being trued and patterned, the shavings peeling off the tough skin almost imperceptibly, so slowly does the elephantine mass revolve. The shape of the grooves gives the shape of the rail to be rolled, and on one of the lathes

a new set of grooves is being cut for a new pattern. Wonderful are the whims of people, even of such seemingly matter-of-fact people as railway engineers! Of every form of rail rolled a brass section is kept as a pattern, the grooves in the rollers having to be made for this template, or section, to fit. There are over 300 of such sections here, differing either in top, or bottom, or waist—no two alike. In the same range as the roller shop is the laboratory, and further on is the testing-office, where a sample of every cast is tested for strength and tenacity, on one of Kirkaldy's dynamometers. Here the steel bars are stretched till they break, the force required to break each bar being recorded in the books. To those who have not seen such an experiment performed before, there is a certain difficulty in realizing that it is only the pull that is making the difference as the piece of steel lengthens and thins in the middle, and snaps with a loud report. The strength of the machine is shown by the bars lying about that it has twisted into corkscrews, the wheel tyres it has made into true lovers' knots, and the chains it has so pulled out that the links, as they have lengthened, have been so drawn together as to form a solid rod.

Having gained some idea of the strength of the material with which we are dealing, let us cross to the steel-sheds again and follow a Bessemer ingot just handed over to the mercies of another mill. With much noise and flying of sparks as it passes the rollers, and clanging and rattling as it slides up and down the inclined planes, it begins as a bright-red block, and ends as a dull-red ribbon, losing in brightness and gaining in length with every squeeze of the mill. At last it rushes up the inner side of the incline, and back again through the end roller, where it receives its final shape, including its name, address, and reference. Thence it passes on to a guideway in the floor, which runs it off on to a measuring-stage, where it is instantly cut to proper length by a coarse-toothed circular saw. It does not take long to make a railway-rail. In twelve hours there can be turned out in this way enough rail to lay a double track two miles long!

We need not linger by the other mills; we can leave

the making of bars and plates as conceivable. Let us end with the railway-rail, which, when it is cut, is slipped away sideways to join its elder brethren, and with them so rarefy the air with its heat that the men and engines seem all on the quake at the work accumulating before them.

CHAPTER VI.

AMONG THE TIMBERMEN.

AT Liverpool the loudest sound that greets us as we enter the docks is the familiar clang and rasp, and by the nearest quayside we find a steamer from Barrow unloading steel rails into a Pacific liner bound for the western coast of South America. Out they come, with a lurch and a swing, some of them on to a trolly to be run up on board on an inclined plane, some of them swinging up direct from the dwarf Barrowite high in the air and down again into the deep hold of the ocean boat. If we are to believe the natives, Liverpool is never busy. It is ever the custom of the shipowner—and the docker—to sing the praises of the day before yesterday. But a stroll along the docks makes it clear to an occasional visitor that the trade is as flourishing as it used to be, and quite brisk enough to prosper under if not to satisfy.

On our way westward we take the inner line. The jetties are crowded with things of strange colours and strange odours, and with strange names but rarely seen out of Custom House lists. And there are other more common objects of the docks. One wharf is crowded with casks imported in staves, and broomsticks in bundles; another is blocked with cases of tinplate and terneplate from Rhondda; another has a barricade of ingots of antimony. In one dock we have to work round a miscellaneous patch of sugar-loaves, soap, cotton and chemicals; the main point of interest in another dock is a hurried taking in of railway carriages as packed from Ashbury's, to which we intend to pay a

visit before our tour is ended; in another is a Cunarder being unloaded in hot haste, hundreds of cases being slipped down slides on to the wharf with as much regularity of interval as the buckets of a river dredger.

Following a pair of big wheels and a beam, a sort of dragon-fly among vehicles, we turn into Canada Dock, and are at once among the timbermen. All about us are logs and balks with strangely-coloured ends, and in replacement of those that are being carried away on the dragon-flies come scores of others extracted with more or less ease from the gaping sides of the timber barques that come from Nova Scotia, New Brunswick, and the St. Lawrence.

Canada is the main source of supply of the Liverpool timber wharf. In no country is the trade carried on under more picturesque conditions. From the time the tree is felled until the log finds it way on shipboard or to the teeth of the sawmill, the surroundings are as romantic and exciting as we need wish. Life among the loggers, from a distance at any rate, seems the very ideal of healthy independence. Drivers, fellers, and explorers all have their definite work, and stand out in bold personality from their background of river and snow. What is this work and how is it done? How is the attack on the woods begun, and how are the victims doomed? Where does the timber come from, and through what adventures does it pass before it reaches our shores?

The war on the woods begins in the good old fashion with a reconnaissance. In the late autumn or early spring, when the leaves are thin on the trees, the explorers set out. A small party they are, five or six in number, fully equipped for a long ramble in the unknown forest. Food, blankets, cookery pots, all have to be taken with them, to be shared amongst their bundles which, secured by the leather strap or 'tump' line, are slung across the chest or forehead. Armed with the hunting-knife and trusty rifle, as their food purveyors, they go forth into the woods as did the trappers of old, but in search of vegetable prey. For weeks they will keep on the move from fresh patch to fresh patch, until some likely spot is reached. Then, climbing a tall pine on the hill top, the leader will carefully survey the

district. If the leafage is not light enough it is no easy thing to tell the value of the timber he can see; but if the branches are fairly bare, it is astonishing how close he will be in his estimate. He has to note the most likely clumps, and consider them with regard to the means of transit. He has to look at the lay of the lakes and rivers, and mark out in his mind the most suitable spots for his camps and landings. In short, he has to glance over the district with the eye of a general and acquaint himself with all its strategic points. Should the survey prove satisfactory, the explorers move to the chosen ground and proceed to mark it as their claim. The roads to it are 'blazed,' that is to say, a notch is chopped in the side of the trees that border the path through the woods, and the destined headquarters are decided upon.

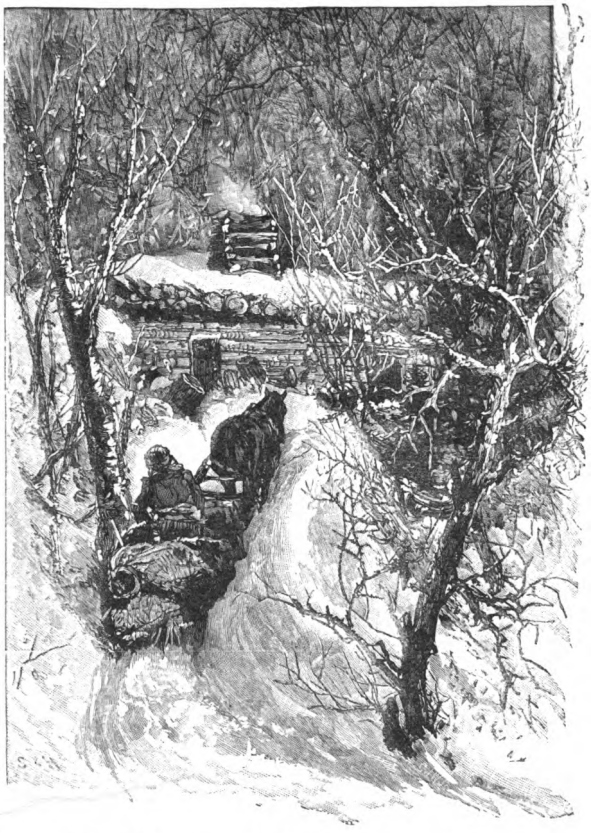
The site having been chosen, the explorers return to civilization. The attack is soon organized, and the 'lumbering' proper begins. Horses, sleighs, and boats are got together. The horses would be idle in the winter were it not for the 'lumbering,' and so to a great extent would the men who start in all gaiety for the woods, though for months they will not see the face of wife or child. Led by the explorer, they reach the field of work and commence proceedings by building their hut. Log-huts are much the same all over the world—four uprights at the corners, logs laid one on the top of the other, with their ends cut half through to fit in with the side logs joining them at right angles—and all over the world their sight is welcome in a solitude. On a cold winter's evening in the woods there is nothing more cheering to the traveller than to come upon one of these huts of the 'loggers' with its light gleaming out over the snow across the river or the lake; for the hut is almost always by the waterside.

As soon as the hut is ready, the 'rollway' is built, extending from the waterside up into the forest. This is the main road, the trunk road in all senses, of the lumbering station; down it the logs are to find their way to the stream. Sometimes it has to be a 'gallery road,' that is to say, a road of which portions have to be embanked or piled, so as to give an unbroken gradient.

To drive this road and repair it is the duty of the 'head swamper.' The foreman's duty is to take the general management of the station and keep the labour accounts. He is supervised when the transactions are on a large scale by the 'bush superintendent,' who rides about from station to station to report as to the general progress of the work. Besides the swamper there are the carpenters to do the general repairs, the sled tender to load the sleighs, the choppers to fell the trees, the sawyers to cut them into logs, the hewers to square the logs, and last, but by no means least, the cook, in general charge of the catering. The catering is not on a very elaborate scale; the drink is almost exclusively strong tea, milkless and sugarless; and the meat is pork and the spoils of the rifle. The only thing on which the cook can show his skill is the bread, which is produced in gigantic loaves, bigger than were ever carried in a free-trade procession. In case of accident, the cook may act as surgeon, and his remedies will probably be of the woods woody; his poultices will be the bark of the moose wood boiled till it is soft, and his plasters will be the tender branches of the ground hemlock, boiled till they are in a state of gum.

The head man selects the tree and decides the way it shall be 'falled,' the direction depending on the shape of the branches, the lay of the land, and the set of the wind. It does not take long to bring down a pine that may have taken two centuries to grow. With a man on each side plying the long-handled axes, the chips fly out at a speed that would satisfy even Mr. Gladstone. In a few minutes the notches are deep enough; and, when all is clear, the last blow is struck, and with a gentle crack, deepening into a roar, and ending in a mighty crash, the pine lies prostrate. Then comes the question, how far can it be 'run up' into the branches? A cut is made in it, and if the wood is not sound a lower cut is made, and so on until the limit is reached.

Then if the trunk is to be squared it is 'lined.' The string is fastened at one end, and, mounting the tree, the foreman moves the line about until he finds what branches should be cut away to trim the trunk to the best advantage.



A JOBBER'S SHANTY IN THE OTTAWA LUMBERING DISTRICT.

The heavy axes then come into play, the branches are whipped off, and notches ten or twelve feet apart are cut, and the wood is split off half an inch up to the line. The hewer then arrives with his broad segmental axe and gives the finishing touch. Should the trunk be left unsquared it is merely cut into convenient lengths, and these are worked on to the rollway and slid down on to the ice or into the water. As with one tree so with the others; and log after log is sent down until the bottom of the rollway is one mass of timber. As the trees are cleared a roadway is run up amongst the stumps and the logs are crowded along the slope. From dawn to dark the work of picturesque destruction goes on; and when night has closed in the men meet round the fire, and the fiddle is brought out, and the evening is spent in musical jollity.

In Ottawa most of the lumbermen are Highlanders, in the older provinces they are half-breeds or French Canadians; and the traveller in the woods may often hear from the log-hut the wild melody of some old Scottish song, or perhaps some sacred hymn; for your Canadian, outwardly at all events, never forgets his church. It is even recorded that the priests make their way from shanty to shanty to conduct religious services in the woods, and that many of these lumbermen, some of them the roughest of the rough, begin and end the day with a form of prayer rattled through with a celerity that would not have wearied even Henry Beauclerk.

Just before the roads break up the lumbermen return to their homes. And when the snow has gone another gang starts to get the logs afloat. This is the most exciting and dangerous part of the whole trade. The logs are on the rollway in a confused mass, one or two of them jammed and keeping back all the rest on the slope. The obstruction has to be cleared; and then with a roar a detachment of the logs will roll helter-skelter into the stream. So swift and sudden is this rush that instances have occurred of men having to spring for their lives into the river, dive deep to the bottom, and swim under water to get clear of the avalanche that thundered behind and above them. All along the riverside the slides will shoot in their wealth of wood.

And these logs have all to be arranged in due order and piloted along the stream. The men who do this are the 'drivers,' of whose exploits the annals are full. Armed with their spiked shoes, and 'driving pike,' a long heavy boathook, they follow the logs, now running on the bank, now springing out into mid-stream, jumping from log to log, easing a rush here, clearing a jam there, righting a heap aground on a shoal, and checking the tendency to swing crossways, as the timber regiment marches past the head of some incoming current. In places where the force of the current is insufficient to move the mass, dams are run across the stream and the water ponded back until, when the timber approaches, the sluice is withdrawn, and the logs rush through on the flood. When the timber is squared and likely to be injured by being hurled over the waterfalls, wooden slides are built, as on the Upper Ottawa, down which it finds its way.

One of the minor excitements of this world is 'shooting' a timber slide. The 'cribs' come floating quietly along the upper river and are steered, or rather poled, into a back-water. All the sign there is of the neighbouring cataract is the roar of the falling water. Slowly the crib enters the gates of the slide, wavers for an instant, bows gracefully towards the slope, slips on to it, wakes to life with a thrill in every fibre, and glides down the glassy, slippery banks like a swallow on the swoop. In an instant the crib is afloat again, and on the lower river with the waterfall in full view.

It is at these slides that the Government duty is collected. As a rule the cribs are twenty-four feet wide, and carry the house of the man and his family, in whose charge they are navigated; it is not only the current that brings them to market, for, like a barge, they are furnished with sail and sweeps. At first the cribs work independently, but when they reach the 'banding ground' they form the units of larger rafts, bound together with wythes or twisted saplings and lashed with chains so as to have full vertical play. In this form they are taken in tow by a steam tug or fiddle-boat, the fiddle-boat being two boats, or rather two sections of a boat, rigged catamaran fashion and having the wheel

in the middle. Slowly the floating village, over the rapids and other dangers, makes its way to Quebec, there to be broken up and shipped to its doom. There is a certain interest in watching the balks as they vanish into the vessel's hold. They are not taken as they come, but are chosen over a wide range. And the selected victim is caught out like a fish, played with for a minute or two till it gets into a convenient position for the iron landing-net, and then slipping along rollers, finds its way into the creel.

When the timber does not 'go foreign' it finds its way to the sawmills, where saws in 'gangs,' that is, side by side on the same spindle, soon make short work of cutting it up. These 'buzz,' or circular, saws are from forty to seventy inches in diameter, and are run up to 800 revolutions per minute. Sometimes they are set a little behind each other, attacking *en echelon* in a 'congregation.' In every mill there are other saws doing other duty, such as 'slashing' saws for cutting slabs, 'edging' saws, 'lathing' saws, etc. A matter-of-fact place is a sawmill, perhaps the most unpoetical thing on earth. In it destruction seems to run riot. Its great problem is how to minimize the 'kerf,' the kerf being the track of the saw. There is no difficulty about the sawdust. If the mill is driven by steam the sawdust goes to feed the furnace; if the mill is driven by water the sawdust goes to poison the fish!

The amount of work that a sawmill can get through in a year is enormous, and the total output of the North American sawmills is almost incredible. Some years ago it was calculated that one town, Chicago, used a thousand million feet of lumber, six hundred million shingles, and one hundred and twenty-one million laths, or altogether sufficient timber to make a 'pig-tight' fence enclosing an area double that of our globe! In the three great timber states—Minnesota, Michigan, and Wisconsin—there was a production of ten thousand million feet, enough to load a railway-train eight thousand four hundred miles long, or to form the full cargo of fifty thousand of the vessels on the lakes. On the Canadian side the rate of consumption will soon be as great.

The growth of a trade is generally a subject for con-

gratulation; it may be doubted, however, if the growth of the timber trade is not a subject for alarm. It takes 150 years to grow a pine-tree; it averages as many minutes to fell it, float it, and saw it into lengths. 'Easy come, easy go,' is the motto of the timberman; and not only of the timberman, but of most of his relatives. To clear a potato-patch a settler will fire a tree, and the fire will be allowed to rage unchecked for miles and miles. On the Pacific slope hundreds of square miles have thus wastefully been denuded of their wood. In Canada picnic parties have lighted a fire to boil the kettle, left it alight when done with, and it has raged over thousands of acres!

Forest laws are not popular laws. Communal rights are hard to deal with. In the early days, when man was less crowded than now, it seemed only just that he should be able to help himself to fuel when he chose; but now that the earth has got fuller, the struggle for existence has grown more keen, and the boundaries of individual liberty have grown more strait. The time when each can do as he likes in his own eyes is fast slipping away. The one is begirt by the many and must subordinate his selfishness to their convenience. He must in most things do the bidding of the majority; and it is undoubtedly for the good of the majority that the reckless waste of timber should be stopped.

That trees affect the climate and thereby the production of the land is an accepted fact. The denudation of the Indian and Chinese hill slopes is the chief cause of the famines in the plains. The destruction of the forests round the gathering grounds of the Volga has reduced the volume of that river and lowered the level of the Caspian Sea. The world is waking up to what it will have lost when the forests are gone, and everywhere a cry is rising for legislation to encourage planting, discourage waste, and keep the crop within the increase. Let us then see what has been done, and in our survey note the principal trees that need protection.

In Canada a start has been made. In Quebec no pine can now be cut less than a foot in diameter. In the North-west territories and Manitoba, the Dominion Government

has taken over the forests, but in the other provinces they are the property of the local governments, who own and dispose of the uncleared tracts. To fell timber a licence is granted, and a fixed duty is payable on all logs cut.

The United States have not got much further than the encouragement of planting, but the subject is fairly under way. The waste in their huge territory has been greater than elsewhere, though the wealth still left is enormous. In addition to the well-known trees of the older States, there is the timber of the rich tracts to the east of the Rockies. There is the redwood, the sequoia of 'the big trees,' useless when grown in the swamps, but hard and free when its home has been on the rolling country. There is the 'curly redwood,' due to the sequoia taking a twist when young, and developing spiral whorls in its grain. There is the Oregon pine, *Abies Douglasii*, the still better yellow pine, *Abies Williamsonii*, the white cedar, the laurel-tree, and that strange figure, Bret Harte's 'Harlequin of the Woods,' *Arbutus Menziesii*, the madrona, with branches of every shape, and bark peeled and scarred of every colour.

Great is the forest wealth of the American continent. South of the States we get in Mexico and the West Indies, between the tenth and twentieth parallels, the straight-stemmed mahogany-tree, *Swietenia mahogani*, which yields the best known of our furniture woods. In Panama, farther south, thousands of people find employment in tapping the local caoutchouc-tree, *Castilloa elastica*. We say the 'local caoutchouc' advisedly, for in Brazil, which has forests half the area of Europe, with 300 varieties of valuable timber, caoutchouc is tapped from *Siphonia elastica* and *Hancornia speciosa*, while in Burmah and Assam in the East Indies, the fluid comes from a fourth species, *Ficus elastica*. In British Guiana are the two shipbuilding woods, greenheart and mora, *Nectandra rodiœi* and *Mora excelsa;* in French Guiana, close by, grows the *Dicorynia* our neighbours use as the angélique.

France was one of the first countries to encourage forest protection, and the wise enactments of Sully bore good fruit down to the days of the Revolution. In 1860 legisla-

tion was resumed, and the result we see in the Nancy school of forestry, which is one of the best in Europe. As an instance of what may be done in tree culture, France has the forest of *Pinus pinaster*, 150 miles long, and from two to six miles broad, which extends from Bayonne to the mouth of the Gironde, and has grown entirely from seed sown since 1789.

In Switzerland the management of the forests rests with the several cantons, and very stringent rules are in force. The chief tree is the silver fir, whose logs, as tourists know, start on their way to market down wooden tramways and iron rope slips. In Italy the 'thick as leaves in Vallambrosa' is no longer an absurdity, for Vallambrosa now belongs to the Government, and is a forest school, while the woods around are cultivated to perfection. As long ago as the fifteenth century the Venetian and Genoese republics had their forest laws, which were suffered to become obsolete with the usual results. One of the curiosities of Italian tree culture has been the introduction of the Australian eucalyptus to the Roman marshes, whose climate it has greatly improved.

Spain has her school of forestry at the Escorial. Austria, with two and a-quarter million acres of forest, has, of course, her academies and laws giving encouragement to planting. Russia also has her forest schools, and her forests, though patchy, are extensive. In the north the timber comes in quantities from St. Petersburg, Riga, and Archangel, the chief being Scotch fir, spruce, and Siberian larch, followed at a considerable interval by beech, ash, box, lime, maple, and walnut. In Russia grows the oak, but it does not cross the Urals; in the Crimea the principal tree is the Corsican pine; in the Caucasus the forests are chiefly of beech and Scotch fir.

Germany is the land of forests and of forest schools. In the estate maps every tree is recorded and felled in rotation. Quite a model of management is the forest of Rippoldsau, at the headwaters of the Kinzig; and hardly inferior to it is that of the Odenwald in Hesse, though Germany's most famous forest is the Black Forest, stretching through the whole length of the Duchy of Baden from

the Neckar to Basle and Constance. Who has not heard of the rafts of the Rhine?

But the chief timber exporting countries of Europe are Norway and Sweden. From Norway 80,000,000 cubic feet come annually, half of them to England; and 23,000 men are at work in the forests and in the timber and woodwork trades in connection therewith. Large as is this production, it is all under control; and no tree is now cut unless another is planted; and only enough are cut to keep within the period of rotation. In Sweden there is a forest department with a director and 700 men, who supervise the planting and felling. In winter the logs are moved about on sledges until they reach the rivers, and they sometimes take four or five years before they reach the port of shipment. The timber is mainly fir and spruce, exported for building, birch, used for fuel, and aspen, used for matches. Sweden has a forest school at Stockholm. Denmark, one of the least wooded countries in Europe, has her forest school. We have none; and in all such matters are far behind our colonies and dependencies.

The Australians are now fully alive to the importance of forest protection, and planting is going on in the hope of preventing the frequent droughts. In 1867 a forest board was formed for Victoria, and the colony has now its State nursery. In Queensland the same spirit is showing itself. In the early days the bunya-bunya tree, which, with its curious cones, formed the favourite food of the blacks, was cut down whenever it was in the way. Now it is strictly protected, and with excellent results. South Australia has taken quite a prominent place with her forest management. The Wirrabara forest, in the northern territory, is well in hand, and the broadcast sowing in the Bundaleer and Mount Gambier forests has told effectually. Australia in the eucalypti boasts the tallest trees in the world, the Californian sequoias being far overtopped. Not only for its sanitary properties in cleansing the air, but for its excellent timber, is the genus worthy of careful culture. And after all, the true policy in tree planting, as in farming, should be the development of indigenous plants. Besides the blue gum itself, *Eucalyptus globulus*, there are the larger *E. diversicolor*,

the jarrah mahogany, *E. marginata*, and the heavy ironbark, *E. resinifera*. Though the eucalyptus flourishes in Australia, neither that genus nor acacia is found in New Zealand, which, however, has some splendid trees, and, by the Forest Planting Act of 1872, entered on the right road to retain them. Of these the best known are the kauri, *Dammara australis*, ranging from 120 to 160 feet high, and girthing at from fifteen to thirty-six feet; the totara, *Podocarpus totara*; the matai, *P. spicata*; and *Vitex littoralis*, the local teak.

From Australia the eucalyptus and acacia have been introduced into India, as has also the cinchona-tree from Peru. The Indian Forest Department is now in a high state of efficiency, and the results of its management are manifest. It is in full work, in the twenty-fourth year of its existence, and has become a popular service for which there is no lack of candidates. All the forests are under its control, even in the native states the woods being held under lease from the chiefs. The principal productions are teak, the best of the Asiatic woods, unequalled for endurance when in contact with iron; cutch, the heartwood of *Acacia catechu*; sal for railway sleepers; sandal wood; lac; and caoutchouc from *Ficus elastica*. Broadcast sowing has been introduced; millions of saplings are in full growth to replace the waste, and the department makes a profit instead of a loss. 'He who plants a tree lives long,' says the Brahmin; and the Forest Department seems assured of longevity, as all have a good word for its work. In Ceylon reserves have been formed, and its choice trees, such as ebony, calamander, and satinwood, are well worth preserving. Burmah is a well-wooded country, and it will, we suppose, eventually come under the Indian Department. Its forests contain a good deal of *Ficus elastica* and teak. And teak is largely exported from the neighbouring Siam, where it grows side by side with the garcinia that yields the gamboge and the isonandra that is there tapped for gutta-percha.

The headquarters of British forestry are at Edinburgh, and it is in Scotland that we have to look for our chief examples of scientific tree culture. Some of the northern forests are of great extent. First, as being the first-planted forest in Scotland, should be mentioned that of Breadalbane,

due to Black Duncan Campbell nearly three centuries ago; then there are the Earl of Mansfield's forest at Scone, the Duke of Athole's larch forest at Dunkeld, and the Earl of Seafield's forest in Strathspey, which is regularly planted and felled so as to cut a thousand acres annually on a rotation of sixty years. The tallest trees the kingdom can boast are the enormous pines in the forests of Mar and Invercauld.

In England we have but little forest left. Only Windsor Forest, Dean Forest and the New Forest are worthy of mention; and yet these hold timber representing two and a half millions of money. They are chiefly worked so as to yield oak for the navy, and are said to be under careful management. The Forest of Dean does not, however, seem to be very thriving, for what with free miners prospecting for coal, pigs grubbing up acorns, and sheep browsing on the tender shoots, its trees are struggling up under considerable difficulties. This is to be regretted, as Dean Forest, if carefully tended, could grow not much fewer than a million of oaks in full vigour. Oak is the most famous tree of our island, though it is probably not as old an inhabitant as the fir and the elder, and, of course, the alder; and it was not predominant in all our ancient forests. In Arden, for instance, the chief tree seems to have been the elm, which from its abundance in the country, is still known as the 'Warwickshire weed.' That the growth of the elm is not so slow as is generally supposed can be proved by a visit to Windsor. In the Long Walk, which was planted, at the restoration of Charles II., with its 1,660 trees to mark the date, some of the trunks are forty-two feet in girth. Our subject, however, not being 'trees in all their branches,' we must here say no more on the inviting topics of girth and growth. We have gone rather far afield from Canada Dock. Let us atone for our diversion by strict attention to business at St. Helens.

CHAPTER VII.

AMONG THE GLASSWORKERS.

THE casting of plate glass takes place very early in the morning, and those who wish to see it have to rise with the milkman. On this particular morning we are bound for the Union Works, in response to a much-appreciated invitation, to see a casting for ourselves. St. Helens, we are told, does not look its best at such a time, should the rain, as now, be coming down in torrents.

It is a great place for glass—even the railway wall is defended with fragments of plate—and for chemicals and for coals; and the glass works and alkali works and collieries are ranged round it in a ring, and from the girdle of chimneys floats a smoke cloud that is quite a wonder. When the smoke cloud is riddled by the rain and brought down in detail, a stain of soot in every drop, the early morning light is cool and grey enough to satisfy the most æsthetic.

The only shop open is a barber's, where strings of telegrams from all parts of the country testify to the consuming interest taken by the St. Helenians in Rugby and Association Football, especially Rugby, which hereabouts is played and talked of with an enthusiasm truly astonishing. The only man we meet is a glass-blower—we can tell him by his lips—whose nose would hardly be taken as a temperance certificate. But really, there is some excuse for him. The filling of some 1,500 quart bottles a day with his own wind must have a tendency to make him dry within. He is now wet enough without. It is, indeed, a dark,

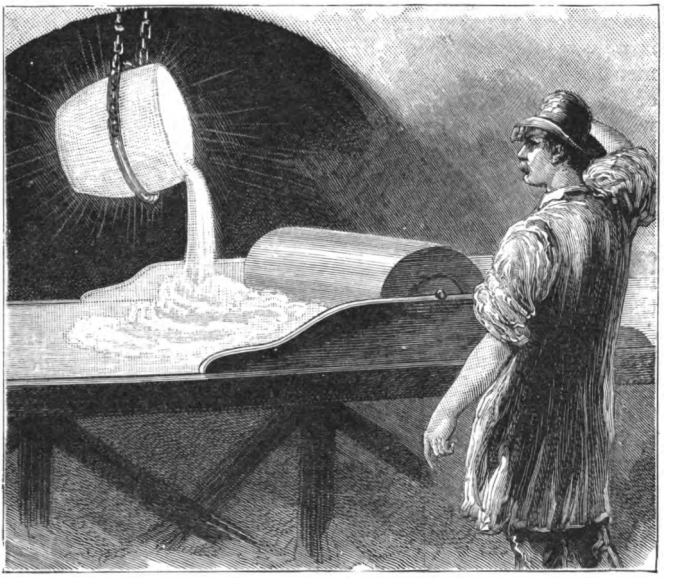
miserable morning, with just enough light to show that a sun exists. Wading through puddles half a cricket pitch across, and slipping and sticking in the clay, we cross the railway and enter the works.

To see the making of plate glass as a spectacle we could not have chosen a better occasion.

A lofty gloomy shed, with a few flickering gas-jets. Noise, there is none, except the pattering of the rain against the panes overhead from which the semi-darkness is admitted that the gas-lights help. All the light worth mentioning comes from the furnace at the far end. One of its five doors is open, and, in a cave of flame so vivid with heat that even the broad tongues of fire are colourless, we can just make out a glowing crucible. Men, with no other clothing than canvas trousers and a shirt hung loosely over them, come past us with a two-wheeled trolly, fitted with a pair of long projecting nippers. The carriage is run up to the furnace; the long arms plunge into the cave, embrace the crucible, and drag it out into the shed. Our eyes can see nothing but the crucible; the darkness around is so deepened by the glare. As the trolly turns near us we get a peep into the huge incandescent fireclay vat, in which the white-hot dough is rapidly darkening into redness, and covering itself with scale. As it disappears under one of the arches we follow it, and find ourselves in a better-lighted shed, in which there at first sight seems to be a series of billiard-tables. The tables are of iron, some twenty feet broad and thirty feet long, built up of many slabs, true and smooth as they can be planed, and fitted with a full-width roller at one end.

The trolly runs the glowing crucible under a crane; the crane stoops and seizes it, and slowly swings it round high in the air until it is in front of one of the rollers. Steadily the crucible is turned over, and out of it on to the table in a thick cataract pours the glowing dough. At the same instant the roller begins to move; like a rolling-pin it squeezes the fiery viscous glass into a thin slab, and when it reaches the end the plate is made. The waste squeezed out, now cooling into transparency, is cut away; the annealing furnace opens at the back of the table; and, with a roar as

of sheet iron, the still flexible glass is pushed in to cool. When the kiln is cool enough a workman will have to enter it to examine the plates, and, in the case of such as are cracked, to lead the cracks with a red-hot iron in the way to do least harm. The side of the plate over which the roller passed is undulating, that on the casting-table is



LIKE A ROLLING-PIN IT SQUEEZES THE FIERY VISCOUS GLASS.

rough; the roller is slightly concave, otherwise it would not work the glass properly; the reason of the table being in separate blocks is, that if it were in one piece it would curve upwards with the heat, and make the plate curved. Even as it is, no sheet of glass is a true plane.

As it leaves the annealing oven it is 'rough plate,' with a crust on both sides. We follow our guide to the grinding-room, where this roughness is ground off. It is a spacious

room, with two long rows of grinding-slabs. The slabs are as big as the casting-tables, and on them the huge sheets of glass are bedded, and ground with sand under a heavy iron 'fly-frame,' said to have been invented by James Watt. The mechanism is ingenious enough, and with its double-crank arrangement quite worthy of the crank's inventor. Between each pair of frames a sort of capstan revolves, and the extraordinary way in which the linkwork moves the frames over the whole area of the slabs is really remarkable. When the plates have been ground they are taken to another room to be smoothened, on another series of low tables on which one plate is rubbed over the other with a little emery between. Again the same eccentric motion brings the whole area into play at every revolution of the capstan. The smooth plate then finds its way to the polishing-room, where the tables travel under a double series of rubbers that, with rouge red as blood, rub crossways, while the plate passes lengthways beneath them. Then the plates, transparent as we see them in our shop-fronts, are taken to the warehouse and stacked side by side, with paper between to prevent them sticking together, for so true in flatness should they now be that, if laid flat on each other, there would be no room for air, and they would never come apart. Here they are examined and cut to size, and such as are discoloured are condemned; but the proportion thrown out to be remelted is not large, for the process is here worked successfully, the secret of success being the mixture which, according to the encyclopædias, should consist of certain proportions of sand, soda, lime, and nitre.

We may as well follow the plate to the bevellers, where the edges are again ground and smoothened and polished in a readily conceivable way. Thence we accompany it to the silverers, where the old mercury process has given place to a much more sure and speedy treatment, in which the hot solution is poured on to the plate, and leaves the silver coating as it cools.

But to plate we must here bid adieu. There is other glass for us to make—'bottle' and 'flint' and 'crown' and 'sheet'—and little space for each can we spare. Bottle glass

is the commonest—'almost anything will do for bottles,' even iron furnace slag has been turned to account for the purpose—but it affords us an example of blowing and moulding that may help us in considering the other varieties. Thanks to Messrs. Nuttall, whose works are within half a mile, we are admitted to the mysteries of bottle-making under the very pleasantest of introductions. Of late we have heard much of a machine that is to turn out bottles at the cost of threepence a gross and the rate of two dozen a minute, for the benefit of enterprising investors who look with disdain upon 'Goschens;' but here let us be content with the newest ordinary method. The furnace is on the same principle as that we saw in use for mild steel at Barrow. It is a 'Siemens' continuous,' and has been at work now for six months, night and day, without a break. Before we leave we take a stroll underneath it, and very hot it is in the tunnel; and there is a certain feeling of insecurity about in that very hot place when we remember the tons of molten glass that are being kept so unpleasantly warm overhead, and think of the gas streaming through the furnace chequer-work and heating up almost to dissociation-point.

There are no pots. The furnace is one huge tank. At one end the mixture of sand, lime, soda, scrap glass, and manganese, or whatever it may be, is shovelled in; at the other end the molten glass is taken out. Within the furnace is a kind of floating bridge, and all the fluid beyond that bridge is ready for the workers. Round the semi-circular end is a series of portholes giving access to the molten sea, and at every hole is a gang of five men and boys.

One of the men dips what looks like a short length of gaspipe into the molten glass, rolls up on its end just enough 'metal' to make the bottle, and rolls the lump of glass on a flat slab of stone called a 'marver;' another takes the tube from him and thrusts it into what looks like a rat-trap, but is really a mould. With a touch of the foot the trap closes, and the man blows down the tube and fills the glass out inside the mould—he does not blow harder than he can help, for he has to blow ten gross a

day! He lifts his foot, the trap opens, and out comes the bottle wanting a finished neck but sticking on to the blow-tube. A lad standing ready with an iron-holder, called a 'punty,' slips it on to the end of the bottle, and the tube is broken away at the other end with a touch of cold water. Held by the punty the bottle is taken to the leader of

BOTTLE-MAKING.

the party, who sits near the furnace hole, and who, taking out a solid lump of glass, fixes it on to the rudimentary neck of the bottle, and with a pincer-like tool forms the familiar ring. To the new-made bottle he applies a template to check its shape and size, and if it contents him away it goes to the annealing oven, where it is allowed

three days to cool; and when the annealing is over the bottles are washed and sorted.

Though bottle-glass is the commonest glass, do not let it be supposed that the colour or form would be different if price would permit. It is, perhaps, natural to look upon the dirty green of a bottle as the nearest approach to clearness that the maker can manage for the money, and to consider the form as in some way necessitated by the manufacture. But the contrary is the case. The restriction as to colour and form comes from the buyer, not the maker. The maker receives from the orderer explicit instructions as to shape and colour, and if the goods are not made of the exact shape and peculiar dinginess required they are returned to be remelted. Bottle is very much like bottle when looked at in a casual way, but wait till you see the samples on a shelf all of a row! And as to the colours being all blackish-green, wait till you see the said greens in regimental order! There is good reason for this exactness. If the colour of the bottles were to vary the colour of the contents would appear to vary; and if the shape were to vary the customer would not be persuaded that he had bought the same brand. A little difference might not matter much, but a succession of small differences would soon be appreciable.

When the drawing of the bottle reaches the works a wooden model is made, and what such a succession of small differences may amount to is evident enough as we look in at the model store. Only a bottle! We were wont to despise you somewhat, but then we had no idea of your seemingly innumerable varieties!

From the wooden mould a plaster-of-paris cast is taken, and from this cast the iron mould is made. The mould is hinged in two or three parts. Some moulds open all the way up, some half way up, but all of them are so designed as to lever together by the worker's foot. The inside of the mould has to be polished till it is as smooth—well, as glass; for if the mould were rough the glass cast in it would be rough. The smoothness of the bottle is the smoothness of the mould.

But of bottles our space forbids us to say more. Let us

take a higher flight to the purest and most beautiful variety of manufactured glass. Of the flint glass process we can have no better example than that afforded by the works of Messrs. Osler, at Birmingham, where the richest of table glass is seen at its best. Let us together make the round of the two factories, where, with much welcome painstaking, our curiosity was so courteously gratified.

And first, let us visit the mixing-room, which in many respects is not unlike a bakehouse. On one side is a baker's trough, long and clean, with the whitest of white sand at one end and the reddest of red lead at the other. In barrels close by are a little nitre and some shining carbonate of potash. These are the four constituents of crystal glass—the purest glass that is made. The oxide of lead is the most expensive of the four, and it comes second in quantity. It is the purest available, for on its purity depends the brilliancy of the glass. It is quite startling in the intensity of its redness.

The sand, which is the chief constituent, comes now from Fontainebleau, where it is found as a fine-grained sandstone, and ground to powder. It is almost pure silica, and it takes the place of the old baked and powdered flints, from which flint glass took its name. In a kiln in one corner we see it drying, and near by it is being sifted and picked over. In the trough it is as white as flour and almost as fine, with just enough of glitter and silkiness to betray its mineralhood. With the pinkish mixture made by these red and crystalline elements—the 'batch,' as it is called—is mixed a certain amount of ordinary glass from the inevitable failures and breakages of the factory; this 'cullet' is carefully gone over, and every scrap with a speck on it rejected. To make really clear glass everything must be clean. The slightest impurity may spoil the whole melting.

The pot is a closed crucible with a D-shaped opening in one of its sides. It is destined to hold nearly a ton of 'metal.' It was made at Stourbridge, like most of its kind, of fireclay and ground potsherds, mixed through fine sieves and trodden into consistency. A strange trade, this of crucible treading. The clay is shot into a bin, above

which hangs a rope from a beam and roof so clean that no speck of plaster can fall. The treader holds the rope as he kneads the mass with the water that is trickled in. First with one foot then with the other, does he squeeze it, the warmth and softness and elasticity of his sole giving a peculiar smoothness to his piecrust of mud. Three times has the whole mass to pass under his feet before it goes on to the pot-builder, who fashions the clay with his palms into small tapering rolls, with which, on a sand-covered stone, he leisurely builds up the vessel that requires perhaps a year to dry.

The setting of the pots in the furnace is the most dangerous task that falls to the glassworker. In the centre of the stone-floored house is the circular furnace with openings in it just large enough to admit of the glass being taken from the pots which stand round its interior, one opposite each small hole; temporary brickwork filling up the gaps through which the pots were put in position. In the centre of the furnace and round and over the pots is the perpetual fire. When a pot is set all hands employed have to be present on peril of a fine. The temporary brickwork is pulled away, and the furnace, driven to its utmost, is exposed. Some of the men take up a long iron bar, and charge with it as with a battering-ram, to detach the empty pot. The heat is terrific; there is quite a fight with the flames. Eventually the white, glowing crucible is levered off, in bits, maybe, and half a dozen men, armed with iron javelins, rush at the fiery furnace, shielding their faces with their left arms and aiming at the rocky crust of clay left by the old pot on the furnace siege. Again and again are the javelins jobbed into the fire, and bit by bit the crust is chipped away. And so fierce is the heat that again and again do the men go back and rest while others take their places. Sometimes four hours may be spent in thus getting the furnace clear. At last all is ready, and the new pot is brought from the annealing stove and placed on the siege, where it may defy the fury of the fire for perhaps a dozen weeks.

The flint-glassworker is not as other men. He begins his work on Monday morning, and he works on in six-hour shifts without a break until Friday midday. Then on

Friday night and Saturday morning the pots are filled with the batch, a little at a time, and on the Monday morning the metal is all melted and ready for the men, each pot providing a week's work for each set of men working at the hole, though only the top of the liquid is used. As

THE GLASSWORKER'S CHAIR.

there are two such sets, one coming on every six hours, night and day, every two crucibles supply one 'chair.'

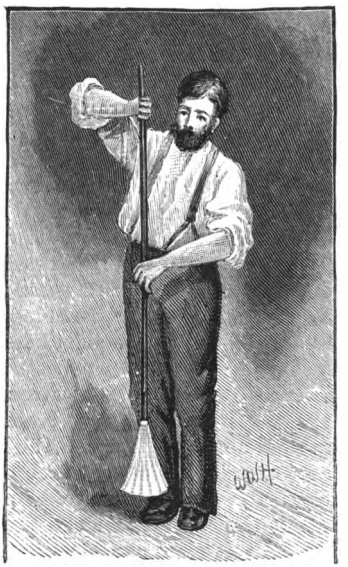
The glassworker's chair is practically his lathe. It is a rough, roomy armchair, with particularly long arms, sloping slightly upwards, on which the long iron blowpipes can be rolled, so as to spin the glass into shape. The occupant of the chair is the 'gaffer,' or workman, and he has three assistants—the 'servitor,' the 'footmaker,' and the boy. The boy begins work at fourteen, and in ordinary course is at least thirty before he rises to gafferhood and occupies the headship of 'the chair,' as the set of four men is called.

As soon as the boy becomes a footmaker he has to join the Flint-Glassmakers' Union, with whom, in a great measure, rests the regulating of his wages. These wages are nominally paid per hour, but are really per piece, for it is agreed beforehand what is to be considered an hour's work, and any articles made over and above that quantity are paid for at the same rate. The work being credited, not to the individual, but to the chair, it is the object of the four members to do their utmost in increasing the output, for all of them share in the increase of wages. The scale is much on the principle of the equations familiar in riddle-books, the boy getting half as much as the footmaker, the servitor as much as the footmaker and boy together, and the gaffer as much as the servitor and footmaker together, which in busy times may reach sixty shillings a week.

The workman sits in his chair, and his three assistants wait on him. Their tools are the 'blowing-tubes'—bars of iron tubing about five feet long, thinned away at the end—and the 'punties,' on which the articles are taken from the tubes to be finished. The workman has the procellos, a sugar-tong sort of tool, in which the blades face edgeways, and serve as chisel and rest in the lathe practice of the chair; another spring tong arrangement, in which the legs are wood; two pairs of shears for cutting, the glass being cut by them as if it were cloth; and the 'battledore,' a square of polished iron used for flattening. A few other tools he has, but these are the principal. They are hung ready to hand on the nails round the chair. Each chair is opposite a gathering-hole of the furnace.

The furnace is seven yards through, and round it are half a dozen chairs in full work, the least experienced men being employed making wine-glasses, while the larger goods are entrusted to the older hands. A cream-jug is made for our especial benefit. A blowing-iron is dipped into the pot, and a lump of molten glass gathered at its end. The gathering of the metal, simple as it appears, requires considerable practice, for just enough must be taken and no more. Take a dozen tumblers and weigh them, and notice how nearly they are alike. The only balance they have been in is the gatherer's hand.

The lump of glassy metal at the end of the blowpipe is taken quickly and steadily to the marver close by, rolled a few times backwards and forwards to consolidate it, and then passed on before it has time to drop or bulge. It is blown into, and becomes a hollow sphere; it is swung in the air to lengthen it; it has a knob of glass stuck to it to



MAKING A LAMP SHADE.

form the foot; it is removed from the blowing-iron to the punty, trundled on the chair, shaped with the procellos, cut with the shears, handled, and handed over a complete milk-ewer, clear as crystal and perfect in curve, in fewer minutes than it has taken to tell its steps. It has not been allowed to rest for a moment from the time it left the melting-pot a lump viscous as treacle and clear as a dewdrop. The manipulation is a triumph of smoothness and celerity; not

a hitch, not a jerk, not a slip, as the cooling is shown by the fading of the rosy flush.

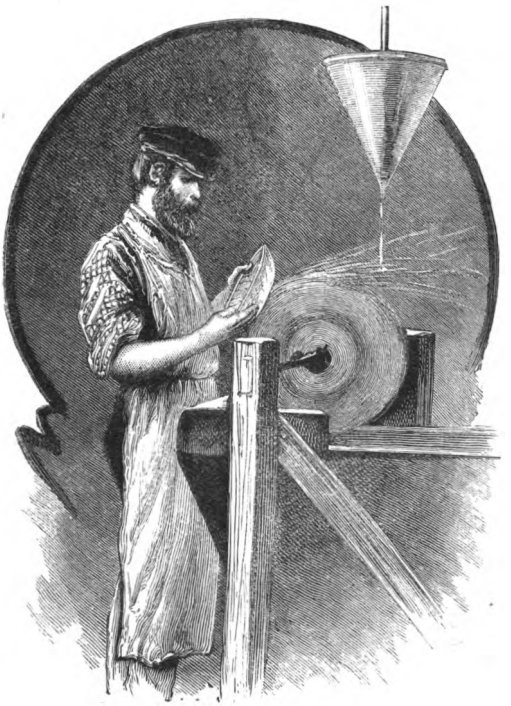
The potter can fashion his clay at his leisure; the glass-worker must shape his metal while it is hot. And he can do great things. Sometimes masses of fifty pounds are worked into shape by a couple of men, and only those who have seen the process can appreciate the dexterity required. At one chair here some large bell-shades for lamps are being made, requiring great bladders of glass to be blown and swung about, as if at the end of a quarterstaff, in a way that is rather alarming, for the balloons are as clear as soap-bubbles, and seem almost as frail.

As soon as the bell, or jug, or what not is finished, it is taken to the annealing furnace at the end of the house. This is a long chamber with a reverberatory furnace at one end, keeping up the same temperature as that of the glass when it enters it, and gradually cooling down until at the far end it is of the temperature of the room into which it runs. Along its floor is an endless chain, on which the trays are laid, on which the newly-made glass is placed. Every hour these are moved a couple of feet onward, and thus they slowly leave the heat.

From the farther room we look through the tunnel crowded with the trays on their way from the fire. At the end near the glass-house we can see the flames playing up both sides and crossing along the arch over the trays. At our end the glass is cold enough to be packed for cutting. The tunnel is the 'lear,' and the process is known as lear-annealing. By it glass can be annealed in twenty-four hours. In the house is a kiln for kiln-annealing, in which the glass is placed and sealed in with clay and left till it cools, which generally takes just under a week.

The glass-cutter works at a frame, in which a thin iron wheel, driven at high speed, derives its cutting grittiness from a mixture of sand and water, that drips on it from an inverted cone. As the wheel spins the glass is held against its edge and slowly cut into. Hence, all the cutting is in straight lines and on the bevel. At Osler's, the cutters stand in rows down each side of narrow, well-lighted rooms, each in front of his sand-covered frame, with

the dripping cone above, the sink below, and the steadily-running wheel of size suitable for the work in hand. Some of the men are ornamenting huge dishes, a foot and more



THE GLASS-CUTTER'S FRAME.

across, some are cutting long pedestals for candelabra, others are grinding in the facets of decanters and epergnes —the light things held in the hands, the heavier ones balanced by counterweights.

One job in progress on the morning of our visit is a set of wine-glasses for the Queen's table. We see the smooth

glass with the opal bloom on it dull as it comes from the annealing tunnel. Then we see the position of the flutes marked out on each glass with compass and red dots. Then we see the flutes being cut on the wheel with the sand and water. Then we see the forming of the facets—a series of lines in one direction crossed by a series in the other direction, giving the wide ring of four-sided pyramids. Then we see the furrows smoothened on a stone wheel, still with sand and water. Then we see them polished on a wooden wheel with glass-cutter's putty—a mixture of oxide of lead and tin—and then we have the glass complete, clear as crystal, with every groove and facet sparkling as if it were in diamond.

But a truce to cutting. In another room we see glass being etched with the usual wax and acid. In another it is being engraved, the tiny wheel of the engraver giving much more artistic finish and brilliancy than the dull, flat ground of the etcher. What can be done by all these processes at their best is manifest enough in the show-room, where, conspicuous among the flash and gleam of the crystal glass, are some specimens of real ruby, in which the colour is due to oxide of gold.

For coloured glass and common glass the great head-quarters are at Stourbridge. The process is much the same as that we have witnessed, only the common glass is moulded as were the bottles, and the coloured glass is made from mixtures containing the colouring matter, the melting-pots being much smaller.

A word may be said as to the making of stained windows, the highest form of the coloured glass industry. This is really mosaic work. So many sheets of so many colours are stained. The design is enlarged to full size and cut up into patches of different colour by lines that in the window are represented by the lead frames. A piece of glass of the colour required is laid over one of the spaces so marked and cut to its shape with a diamond; all the pieces of that colour in different parts of the picture are similarly cut to fit; then another colour is taken, then another, everything being cut out of the sheet except the faces and hands and a few trifles it is impossible so to treat satisfactorily, and

which are produced by processes more or less the secret of the maker; and then the pieces are fitted together as if the window were a fretwork puzzle. The glass used is not 'flint,' but 'sheet,' or 'crown;' and thus we are brought to the consideration of the next branch of the glass manufacture.

Crown glass is made of sand, ground limestone, carbonate of soda, and sulphate of soda. It is melted in much the same manner as flint glass, only the pots have no hood. When the pot is charged a ring of fireclay is placed at the bottom and the mixture thrown in. As the mixture melts the ring rises, and when the metal is ready for dipping the ring floats on the top.

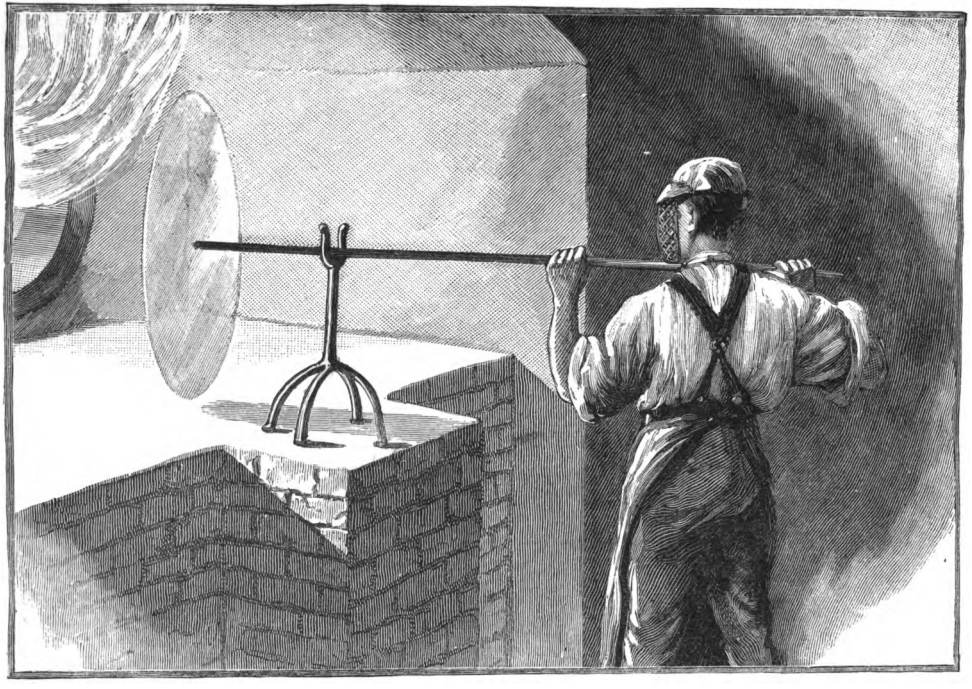
The gatherer dips his pipe or tube inside this ring, and with a twirl collects on the end, or 'nose,' a pear-shaped lump. He then rests his pipe on a stand and turns it gently round until the lump is cool enough for the second gathering. When he has enough of the metal to work with he cools his pipe under a trough of water, and proceeds to roll the lump into a conical shape on the marver. While it is being trundled to and fro, and consolidating, a boy comes forward and blows down the pipe until the cone becomes a hollow globe. The globe is heated and again blown, and becomes a Florence flask, the 'bullion-point,' the apex of the old cone, being still conspicuous, and the flask being so rolled on the marver as to form the rim of the future plate near the nose. Again it is heated and blown into a larger sphere, with the bullion-point exactly opposite the nose, the pipe being rested on an iron support, and a boy holding the point in position with a small cup. The sphere is taken to the fire and spun and blown as it spins, so that the front is flattened. The sphere becomes a huge, short-necked decanter. The pipe is laid on the rest, and a lump of glass on a punty is fixed to the bullion-point, and forms it into a 'bull's-eye.' A piece of cold iron is thrust into the decanter, near the nose, and the pipe breaks away from it.

A man with a veil before his face now takes the glass on the punty to a fierce circle of flame, and in it twirls the neck of the decanter. Round and round it spins, melting

and opening, flatter and flatter, until it becomes a circular plate, like that of an electric machine. Still whirling, it is withdrawn from the flame, laid upon the 'whimsey,' cut from the punty, lifted with a fork into the annealing-kiln, and piled upon its edge on the 'table' that preceded it, and kept from close contact with it by the bull's-eye and an iron frame. In forty-eight hours, at the outside, it is taken from the annealing-kiln and laid in the warehouse on a 'nest,' or cushion, to be cut up by the 'splitter' to the best advantage. The 'table' of crown glass is from four to five feet across, and great is the judgment required in dividing it into pieces of different quality, so as to get as much 'best' out of it as possible. The most remarkable stage of the crown process is that before the nose-hole, when the veiled man is whirling the growing bulb in the circle of flame, and the bulb, fluttering into flower, curves outwards ever more widely, until it is a thin, solid wheel of wonderful brilliancy a yard and a half or more across.

It is its peculiar brilliancy of surface, due to this flashing at the nose-hole, which has enabled crown glass to make such a good fight with its great rival 'sheet.' Sheet glass is melted in the same way, but instead of being rolled on a marver it is manipulated into a cylinder on a hollowed block of wood. The wood is sprinkled with water to prevent its being burnt. The hollow in it is practically a mould, for it limits and fixes the size to which the cylinder can be blown.

At the blowing-furnace every blower has a hole to himself. In front of each opening is a wooden stage erected over a well about ten feet deep. When the cylinder as it leaves the block has been heated sufficiently in the furnace, it is brought out by the man on to the stage, and there blown and swung round and up, backwards and forwards, until it is of the required size. The diameter remains as given by the block, but the length is much increased. As the pillow of glass slowly lengthens it seems as though the man were engaged in some startling juggling feat. Now the pipe is held vertical with the end in the blower's mouth and the glass aloft. Next moment it is swinging like a pendulum, or flourishing overhead as if it were a fly-rod or



MELTING AND OPENING, FLATTER AND FLATTER, UNTIL IT BECOMES A CIRCULAR PLATE.

the handle of a stock-whip. Now it is dodging about in so eccentric a manner that we can only suppose the workman is 'showing off' with a view of impressing the stranger.

We have seen the bladder blown, and we are privileged to see it burst. A good puff of air is blown into it and the end of the tube is stopped, the cylinder is held to the fire, the heat expands the air, at the weakest and hottest

NEXT MOMENT IT IS SWINGING LIKE A PENDULUM.

part there is an explosion, the glass is burst open, and the pipe is turned until the rent becomes the full size of the end. Thin glass is generally opened in this way, but with thick glass a lump of hot 'metal' is stuck on, and at the part so made hot, and therefore weak, the burst takes place, the opening being cut to shape with the shears.

The cylinder—some six feet long—is then laid on the wooden 'chevalet' or stand, and with a piece of cold iron it is detached from the nose. Round the cap a thread of glass is run and taken away immediately, and a piece

of cold iron is held to the heated ring, which at once becomes a crack, from which the cap breaks away. A wooden rule is held inside the cylinder, and a long-handled diamond run along it splits the cylinder open. The cylinder is taken to the flattener. In his furnace is a stone with a piece of glass on it; upon this so-called 'lagre' the cylinder lies with its split side uppermost, and the flame playing over it until it opens and falls back into a wavy sheet. Then the flattener takes a block of wood with an iron handle and proceeds to rub the wavy sheet quite flat. Then the flattening-stone is run along to a cooler part of the furnace, and the sheet forked off on to the cooling-stone. Then, when cool enough to be left, it is taken out, and waits, on its edge, to be annealed.

Sheet glass is the common glass of our windows. Would that it were all home-made! Sometimes our glass-makers get a good order, but most of the good orders have now passed into legend. One, the most famous, was that for the 1851 Exhibition. The cylinders were blown to cut forty-nine inches by thirty, and this was divided into three panes, each forty-nine inches by ten. Some 300,000 of these, totalling up to 1,000,000 square feet, and weighing over 400 tons, were made at Chance's in a few weeks without absorbing or interrupting the ordinary output. And the energy of the glaziers equalled that of the glassworkers. In one week 18,392 panes were fixed in the roof by eighty men; and one man excelled all others, and accomplished a 'best on record' by fixing nine dozen panes in a single day!

Farewell to the glassworkers. To-morrow morning we are due in Manchester to study quite another phase of industry.

CHAPTER VIII.

BUILDING A RAILWAY CARRIAGE.

THE carriage in which we travel suggests a train—well, there is really no help for it, and the unsought pun must pass; we might say 'line,' but that is just as bad—it suggests, then, a train of thought as to its origin and cost which we resolve to follow out in more detail. And we do so, as time offers, with results that may fitly be recorded here.

Of the millions that travel by rail how few there are that know how costly an affair is the carriage in which they ride! The Limited Mail, as it leaves Euston with its engine, passenger-coaches, brakes, and post-office vans, is worth nearly £15,000. The Brighton express is worth nearly as much, for Pullman cars cost £2,700 apiece. The ordinary carriage used in the Midland expresses, containing three first-class compartments, four third-class compartments, and a luggage-box, costs £1,097; and the cheapest carriage used on the line—the six-wheeled third-class, with its five compartments—costs £390.

The money invested in our home railways exceeds our National Debt by £120,000,000. The value of the rolling stock alone is enormous. On the 1st of January, 1888, the united companies had on the rails 15,552 engines, 35,021 passenger-carriages, 12,667 brakes and other vehicles attached to passenger trains, and 487,237 goods-waggons—and even the waggons are worth £60 each at the least!

The cause of the cost is obvious. Labour and material

must be of the honestest and best; a scamping in the work, a defect in the wood, a flaw in the metal, may mean the destruction of the train and the loss of many lives; and even the ordinary wear, with the continual jolt and strain, requires that the vehicle should have as few weak places as Holmes's immortal chaise. During the railway race of 1888 a train with two engines ran out from Newcastle for Edinburgh, and covered the 124 miles in 124 minutes, so that, roughly speaking, in the two hours each of the heavily-loaded carriage-wheels — and a carriage weighs fifteen tons—made 50,000 continuous revolutions. This was a high trial, but it is worth remembering as an example of what a railway-carriage may be called upon to do.

We have said that a carriage weighs fifteen tons. A Pullman sleeping-car weighs twice as much, but it is the heaviest vehicle at present on the rail. In locomotion increase of weight is due to the desire for increased strength and speed. The heavier the carriages, the heavier must be the engines; and there would be no limit to the increase were it not for the difficulty in maintaining the track. So great is the friction with the present weights that every hour throughout the year fourteen hundredweight of steel disappears off the London and North-Western system. A huge undertaking is the North-Western of to-day, with its capital of £108,000,000, its 1,800 miles of system, its 650 stations, and its working staff of 55,000 men!

In the far past of railway history its first-class carriages weighed three and a quarter tons, and each had only three compartments, with three passengers on each side. That was in the days when the London and Birmingham Railway considered it so beneath their dignity to carry coals to London that they introduced tarpaulins for the purpose of hiding the vulgar freight of which they were ashamed.

'What! Carry coals! They'll be asking us to carry manure next!'

'And why not?' asked George Stephenson.

And the solid reasons were not forthcoming, and railway

companies nowadays are not too superfine to carry 'minerals' exposed to the sight of all men. Though they turned up their noses at coals, they were not over particular in their accommodation for passengers. The third-class carriages were mere tubs, improved in time into cattle-trucks. When the 'covered cars' came in, that was luxury indeed! Even the second-class passengers then had, on a wet day, to put up their umbrellas to save themselves from being drenched by the rain pouring through the lamp-hole! The improvement has been vast, except on some of the south-country lines, whose third-class curiosities are apparently kept going until such time as the Channel Tunnel allows of their being lost on the Continent.

Many of the larger lines build their own vehicles. The North-Western, which keeps going 4,500 passenger-carriages, has its works at Wolverton, half-way between Birmingham and London, where fifty acres are covered with timber-stores and workshops. The making of a wooden wheel at Wolverton is a sight to remember. Down among the lathes, which in double row are placidly paring away steel tyres and axles as if they were mere bits of apple or potato, a tyre is swung aloft on to a hydraulic press and a few segments of teak placed on it. The tyre has been spun from a solid mass of Bessemer steel without a weld, and the wood has been cut and shaped in the saw-mill by automatic machinery. The press descends, the segments groan as they feel the pressure, and seem to struggle obstinately against being squeezed into the rim. But down they go, and with a few thumps to drive them home, the wheel is lifted, looking as if it had been carved from solid teak.

The North-Western makes its carriages at Wolverton, but its waggons, of which it has 56,000, it makes at Earlestown, just north of Warrington, where thirty-five acres are devoted to the purpose. Here there is one shop over 150 yards long and nearly 100 yards wide; near it is a saw-mill over sixty yards long; not far off are two smithies, with over 100 fires, and turning and spring-making shops, foundries, and forges, all fitted up with the newest machinery for

giving the greatest amount of power and facility with the minimum of labour. Adding together Crewe, where the engines are made, and Wolverton and Earlestown, the North-Western rolling-stock works extend over 200 acres.

And as the railway made Crewe and Wolverton, so did a railway make Swindon, and with even less of a nucleus. Few there are who will forget Richard Jefferies' description of the beginnings of the great railway town, when Brunel and Gooch sat down to their sandwiches among the furze-bushes and agreed by the pitching of a stone that on that spot they would have the centre of their great railroad. The early history of the Great Western is the most striking in railway story. The haste to open it was such that no obstacle was allowed to stand in the way that lavish expenditure could remove. Where a cutting had to be excavated land was bought on which to throw the excavated soil; where an embankment was required an adjacent hill was purchased merely to provide the material. The work went on regardless of weather; the saturated clay slipped away to its angle of repose, and piles were driven to restrain it; the piles slipped, and chains were linked from pile to pile to keep them upright; and the trains now run at Swindon over tons of cables buried in the earth.

And almost as interesting are the early chronicles of the Midland, whose projectors were far more thrifty. Who that has travelled on the line has not had pointed out to him the church of the village of Eastwood, at whose Sun Inn there came into being the great railway company whose headquarters are now at Derby, and whose works are one of the great industrial centres of the Midlands? In its carriage-shops alone there are more than fourteen acres of buildings and ten miles of sidings, and a staff of over 2,000 men. In the yard are ash and elm from our own country, teak from Burmah, mahogany from the Gulf, black walnut from the States, deals, red, white, and yellow, from the St. Lawrence and the Baltic—over 10,000 tons of wood in stock in process of seasoning. The saw-mill is 320 feet long and 200 feet wide, a pleasant sky-blue pande-

monium of whirring tools—sawing, planing, moulding, shaping, mortising, tenoning, boring, turning, dovetailing—all in full chop and scoop and spin, among them, in grim esurience, a vertical saw with fifty blades, gnawing eight feet along in an hour at the rate of 100 strokes for every inch. In short, here is a wilderness of ribbons and wheels, the powers of which are so varied and perfect as to enable a couple of men to build complete an ordinary goods waggon in a day.

An ordinary goods waggon carries eight tons. The first goods waggons were merely platforms, with sides of from four to ten inches high; there were no buffers; then the buffers appeared at one end; then they came on at both ends; and now even the chains are fitted with springs; and a waggon is considered badly made that will not carry sixty per cent. more than its own weight. There are the covered waggons, costing £72 apiece, and weighing five tons three hundredweights; there are the coal trucks, costing £68, and weighing five tons two hundredweights; there are the low-sided coal trucks, costing £61, and weighing four tons fourteen hundredweights; there are the cattle waggons, costing £86, and weighing six tons; and there are coke waggons, gunpowder waggons, salt waggons, lime waggons, ballast and other waggons—all required to make up the goods rolling stock of a great railway. And the passenger stock is in almost as great a variety. There are first-classes, second-classes, third-classes, composites, luggages, brakes, horse-boxes, carriage-trucks, travelling post-offices—all like the goods vehicles, similar in the main, but differing in detail on every line according to the peculiar whims of the engineers.

The scope there is for these minor differences can only be seen at such a place as Ashbury's, near Manchester, where railway rolling stock of all kinds is built for all parts of the world. At Ashbury's, which covers twenty-six acres, there are employed some 1,500 men. These are well cared for; there is the usual kitchen arrangement for warming-up the breakfasts and dinners; there is a library, and there is a recreation-hall, with orchestra and platform. As at Derby, the great sight is the wood-yard, which here contains over £10,000 worth of timber, a larger proportion than

usual being teak for the foreign trade, owing to its more lasting qualities on land or in water. Insects do not like this wood, although in India and other places, where the carriages are eaten by white ants, sheet-iron has to be used instead even of teak.

The wood is delivered by the Manchester, Sheffield, and Lincolnshire line, which forms the southern boundary of the works, and is kept in logs for a year out in the air to season. Then it is taken under shelter, and in time finds its way to the saw-mill, where it is dealt with by a frame in which forty-three vertical saws can be worked at one time, or else it is handed over to the tender mercies of a large circular saw with eleven terrific teeth, which roar into it with such vigour that it seems to flinch on the travelling slide as it slowly moves to its doom. Cut up into planks, it is passed on to be further cut up into standard lengths. And the amount of sawing that goes on may be guessed from the output of sawdust, which averages 100 bags a day.

The vehicles are built to order. An order for a railway-carriage is not only accompanied by a full specification, but by a complete set of scale drawings, in which every detail is set out, down to the shape and dimensions of the very bolts and screws. No option is left to the builder; the conditions are as strict as if instead of a carriage he had been ordered to produce a locomotive. From these drawings working drawings are made for the different departments, and the workers in wood and metal start simultaneously on the various pieces of the puzzle, which are expected to fit like watchwork when put together.

Let us take the woodwork first. The standard lengths are first introduced to the 'clipper,' a series of revolving knives that serve the purpose of the jack-plane. They then pass on to the 'smoother,' a fixed knife, against which they are driven, and long thin shaving after long thin shaving removed from them until they are of the desired thickness and evenness. Beautifully do the smoothers work; some of the shavings are a couple of yards long, and as thin and silky as the finest foreign note-paper.

Then the wood is shaped, and bored, and carved, all by machinery. There are ribbon saws—endless tapes of metal working over pairs of rollers, and always running in one way—and fret-saws, with the usual up and down motion, cutting the most elaborate patterns. For the borers there is a pattern with holes in it, the holes being punched through to give the marks; but when the boring is begun it is not continuous; the tool advances and retreats, and then advances through; there is always a dwell, to keep the steel end cool. The cutters of the carving machines are sections of double cones, so as to strike twice at each revolution, and a similar arrangement of cutters performs the dovetailing. Even more ingenious arrangements are the cutting of the mortises in such woods as teak by the fierce steel teeth, and the cutting of the louvres, which a boy does on a mitre machine, while another boy planes them, holding them down with his hand. The edges of all these tools are as sharp as those of a surgeon's knife; the keener they are the better they work and the longer they take to get hot. The sharpening is all done in the shed, the most noticeable appliance for the purpose being an emery disc in one corner ablaze with fireworks, the sparks showering off as if from a catherine-wheel.

But for fireworks we must go to the ironworkers, and see the spongy masses of malleable iron gripped out of the puddling furnaces and hurried to the hammers to be kneaded into blooms, all in the good old style, with the men around in face-screens and leg-guards, and very little else, shining with perspiration in their heavy armour. The cams on the sturdy wheel toil round, and as each passes, down with a jolt comes the clumsy helve, and the sparks fly and the metal glows and flashes where it is struck, and the heat is painful, and the mass rolls over and is pounded by the helve, jolt, jolt, knocking it smaller every instant with a bitter reiteration that is almost human; and then the discredited bloom gets into the mill, to be drawn out longer and longer, while the ground around is covered with the rough charcoal biscuits it has thrown off in scale. Or if we like not the old style we can have the new, and see the blooms pounded into shape by the steam-hammer.

There is foundry work enough to satisfy any lover of the industrial picturesque, for there is a forge output, in small pieces, of fifty tons a day. There are twenty puddling furnaces, and twenty boilers are heated with the waste gases from the furnaces, and there are seven steam-hammers and two rolling-mills, and a remarkably vocal saw for cutting red-hot iron. There is a smithy with 150 fires, and a brass-foundry with five furnaces. The appearance of all of which is conceivable, the prettiest effect being perhaps that in the foundry, where the thin bright streams of molten iron are in full flow on their way to solidify into axle-boxes and such-like furniture.

But the most interesting operation, as at Wolverton, is the making of a wheel. This time let it be a common one, such as we see on waggons, and which are rarely used in the passenger-work of the best lines. The solid wheel is the best by far. It has no spokes, to give unnecessary resistance by beating the air, nor does it raise the dust from the ballast, to find its way into and do damage to the axle-bearings. It may be of wood, or paper, or plate-iron; it matters not so long as it is practically spokeless. Unfortunately, however, it is dear, and, though almost necessary for express-work, its advantages at slower speeds are not so great. Hence for goods-waggons, foreign traffic, and minor lines, the open wheel does well enough.

Let us, then, watch the making of a common wheel. From the fires come three men, each with a short length of metal. The lengths are laid on a mould. A valve is touched, and on all sides hydraulic presses grip the metal and weld it into a triangle, with two straight sides for the spokes of the coming wheel, and a curved base, which is a segment of the circumference. Sometimes it is one piece of iron that is laid on the block and forced by hydraulic pressure into this triangular shape. Then the segments of the circle are heated at their ends and laid together in wheel-shape, and to the gap in their centre is brought the glowing boss, and on to it comes the hydraulic ram, and with a squeeze the ends of the spokes and the boss are welded into one piece. It is all so quiet and quick. There is no noise

in hydraulic work. Three bits of iron, a quiet squeeze—they are one! Six or eight triangles side by side, with their inner angles open; a lump of hot iron is laid on them; a quiet squeeze; the triangles have disappeared, and in their place is the wheel! The ram that for a moment conceals the work is more wonderful in its effect than the magician's handkerchief.

And the ram puts on the tyre, and when the tyre is trued in the lathe—a funereal progress, without an advance, in search of veracity—it is the ram which squeezes it on to the axle. A telling example of water-power, this! The axle hung between the ram and the dead block, the wheels at each end, the gauge between, the touching of a lever and the slow approaching of the wheels along the axle until the gauge-mark is reached; no shock, no jolt, smoothly, as if greased, the wheel is thrust on irresistibly, without the slightest sound, and 150 sets of wheels and axles can thus be dealt with in a week. Later on, when it comes to fitting together, the hydraulic is again brought into play, and with a pair of huge pincers the rivets are nipped and finished without a blow being struck.

All being ready—the woodwork and the ironwork, the frame and the body, the wheels, the laminated springs, the bars, tie-rods, brackets, knees, straps, bolts, nuts, and the furniture—the carriage is put together and upholstered and finished. The painting is a long job. Before it is over two dozen operations have to be gone through on the thirty carriages which stand in the shed at one time. The upholstering does not take so long, but the material is more expensive. In a first-class carriage even the ceiling-cloth costs two shillings a square yard, and the horsehair in only one of the compartments may be worth from £5 to £8. The thick glass in the quarter-lights, the thinner plate in the door-lights, are not bought for nothing. Trucks do not want upholstering or glazing or panel-painting; they are mere unfinished trifles, so to speak. Ashbury's turn out a truck complete every fifty minutes, the output for a week being 100 waggons and ten carriages of the largest and most finished build. One strange thing about a railway-carriage body is that it all

takes to pieces like a bedstead, and that seats, sides, and partitions can all be laid on the floor and sandwiched between it and the roof. As packed for export, it goes into a flat case, narrow and long, and takes up little more room than its underworks.

Carriages nowadays are much longer than they were. The longest four-wheeler measures forty-five feet, the longest six-wheeler is fifty-four feet. The six wheels were introduced in order to give more ease round curves by allowing a little lateral play to the centre set of wheels. In the bogie carriages we have a further advance; the wheels of the bogies with their short reach being able to negotiate any reasonable curve, while the long carriage-body being pivoted on them they are enabled to swing, so as to form the radii of almost any circle. The bogie was invented by George Stephenson in 1833, and applied to an engine sent out to America; there the principle grew into such favour that at last it recrossed the Atlantic. It was the Pullman car that popularized the bogie in this country; but our northern companies have now surpassed the Pullmans in length, whose forty-nine feet over all is often exceeded.

Every company has a distinctive pattern and colour for its carriages; and strange combinations some of them are, particularly on foreign and colonial lines. When we were at Ashbury's there were some Spanish carriages in hand. These were of iron, painted a dirty slate colour, with a bolt outside at the bottom of the door, so that the guard could keep the passengers in safety; windows there were none; all was solid; even the sliding window in the door was a sheet of iron, and the only means of lighting the carriage was through two little peep-holes of glass, each six inches by four inches, let into the sliding shutter which took the place of the window. These carriages represented the extreme of discomfort. There were others of more ordinary type; some destined for Tasmania, some for Singapore, some for nearer home; but the extreme of comfort was a beautiful coach painted in yellow and stripes, perfect as to light and ventilation, with louvre boards round the roof, and a sunshade as a cornice, and the most gorgeous fittings and upholstery imaginable. And this boudoir upon wheels

was for the private railway of the Rajah of Morvee. Who this potentate may be we do not know. We made but one effort to discover, and that probably failed owing to the Gazetteer we consulted being of our own editing. But he is evidently a superior person. No three classes for him, but an improvement on the Midland mixture of first and third. His travelling bijou bore in four-inch letters the bold inscription UPPER CLASS!

CHAPTER IX.

A REEL OF COTTON.

'NOW, ladies and gentlemen,' said a cheap jack, after trying in vain to sell a tool basket, 'I beg to introduce to your notice another vegetable compound!'

It was a reel of cotton! and, though far-fetched and but feebly humorous, 'vegetable compound' was a fairly true description, for cotton, reel, and label are of plant origin in more senses than one. The cheap jack's reels were, however, suspicious, as well as familiar objects, for there is a 'philosophy of reels' not known to the majority.

'My dear,' says one of Mr. Gilbert's unlovable heroines, 'we will have a three-quarter cake.'

'Whatever is that?' asks the would-be bridegroom.

'Why, wedding-cakes, you know, are now made of certain proportions of cake and wood.'

'Oh! I see! How charmingly thrifty you are! You mean to have one that is three parts cake?'

'No, my love, one that is three parts wood!'

And there is a similar practice in cotton reels.

'This,' said a manufacturer to us, 'is a class of goods we make for the English market. The spool, you see, has the same sized ends as the others, but the body is of slight diameter. It holds 400 yards of good cotton. It is a good article, and people can pay for it. This,' picking up another, 'has the same ends, but the body is much thicker. When complete it looks the same as the other. But it only holds fifty yards. We make it for the Irish market. Ireland is a poor country, and its people have not

much capital to lay out at a time, even in sewing thread. You can tell the wealth of a nation by the shape of its cotton reels!'

And before us lay the world displayed from this point of view—reels for Palestine and Fiji, for China and South Africa, for Norway and Sweden, and Italy and Labrador, for Chili, Bulgaria, and Russia. 'The last case that will go, owing to the Russian custom-house now charging us duty both on the cotton and the wood, so as to throttle our trade.'

Where do the reels come from? Most at present from home-grown wood, of ash or birch or anything that will not chip, from Scotland or the Lake district, where the stampers and turners are being driven to foreign timber, owing to the demand for reels growing quicker than the trees.

And here we have again struck the botanical track, and may as well follow it up. All know, or ought to know, that pretty wayside plant the mallow, with its large purple-striped flowers, and its cheeses beloved of children. That common mallow, *Malva sylvestris*, is the type of the natural order Malvaceæ, to which the cotton plant, *Gossypium*, belongs. Into how many species the *Gossypium* genus may be divided depends on the whim of the botanist. Some make a dozen species; others only two. Let us follow the school satisfied with two. The amount of technical knowledge then required of us is not overpowering. Species No. 1 comes from America; species No. 2 comes from anywhere else! This classification cannot, however, be accepted without a qualm, for surely we ought to have a separate species for *Gossypium religiosum*, the widely-branching cotton-tree held sacred by the Hindoos, from which comes the janeo of the Brahman —that three-fold cord, forty-eight yards in length, twisted and folded into three, again twisted and folded into three and knotted at each end, and bestowed at the youth's induction.

Cotton is the Gossypium's hairy seed, and the longer and stronger the hair the better for the purposes of trade. The

best cotton in the world used to reach us from the low-lying islands off the coast of Georgia, but now the so-called Sea Island plant has been acclimatized in Queensland, and Fiji, and Tahiti, and Egypt, and has not lost all its merits. Roughly speaking, the longest cottons come from America and Egypt, the shortest from India, where cotton has been used for clothing for twenty-four centuries at least. Did not the woollen-clad soldiers of Alexander reckon among the greatest wonders they saw, 'the wool that grew upon trees'? Even China got its cotton from India in historic times; and, as to America, the trade is but little more than a century old. Who has not heard of the first eight bags consigned to William Rathbone in 1764, which were seized by the Liverpool custom-house officers on the ground that 'so much cotton could not have come from America, and was liable to seizure under the Navigation Act on account of its not being imported in a vessel of the country in which it grew'?

But our business is with the present, not with the past; with the reel of sewing cotton in the hands of the cheap jack. How is the seed of the mallow-like plant made fit to pass through the needle's eye? In the first place, the seed is got rid of as soon as possible. The cotton is 'ginned'; the seeds, in shape not unlike unground coffee, are removed, and the fibre, forming about a third of the mass, is taken out and exported in the bales which form such prominent objects on the Liverpool quays. On reaching the spinning mill the cotton is mixed, or blended, with other cotton to get the necessary quality for the work in hand, and down a long shoot it finds its way to the first of those beautiful machines which are the pride of Lancashire. This is the opener, consisting essentially of revolving teeth, running 1,400 times a minute, to loosen the fibres and shake out the dirt. Then it goes to the scutcher, the invention of one Snodgrass, a Scotchman, from whom its name is asserted by some to be derived. The scutcher serves the fairly clean cotton much in the same way as the opener did, but it does its

work more carefully, and turns out the fibre in a thick fleecy mat, or 'lap,' which is wound round a roller as it passes out of reach of the beaters that have hammered at it so mercilessly. Prosaic processes these, the machines uninteresting, doing much of their work in concealment, stowed away, perhaps, in a cellar, two or three only together.

It is with the next step that the cotton comes into view and makes its first presentable appearance. The laps are brought to the carding engines, whose business it is to brush it and comb it with many thousand teeth until its fibres are all stretched out and laid parallel to each other. A cylindrical comb revolves, dragging the fluffy cotton from the lap, and bearing it along against line upon line of rollers and cleaners, all bristling thick as they can stand with fine wire points. It is hair-brushing by machinery with a vengeance! From the cylinder, the fibres all truly laid and changed from the felted mat into a thin layer of silky whiteness, pass over a doffing cylinder, and with a beautiful motion throb out into a trumpet-shaped guide, down which, as a soft fleecy rope an inch across, they coil their way into tall tins.

Then these ropes, or 'slivers,' go to another machine and are further combed, and then they are 'drawn' and lengthened, the secret of the lengthening being the passing of the rope over four small rollers, each revolving faster than the last, so that the sliver running through is always under tension. To every drawing frame there are generally three drawing boxes, six slivers being led to each box, the six drawn into one by each line of rollers going at a greater speed, the front roller travelling six times as fast as the back. And in long ranks, close as they can be put, stand the drawing frames on the spacious floor, say 150 feet long and eighty wide; a solid square of machinery, black in the mass; broken with the grey of the whirling spokes, the bright lines of polished steel, and the narrow white streams of silky fibre flowing smoothly into the polished cans. Every rope runs over what is practically a hair trigger. Should

the rope break, the pressure on the trigger is removed, and the catch drops and stops the machine. In this way is the uniform thickness of the rope assured. Many as are the frames, and great as is the noise of their movement, the stoppage of one can be instantly detected by the sound alone.

And so, continually thinning and increasing in the number of strands, the rope goes from machine to machine, getting in its later stages a gentle twist from the revolution of the tins as it is stowed into them. Finally it reaches the spinning floor, and with a roar as of a train in a tunnel it is spun. The noise made by the thousands of bobbins and the things that drive them is, in truth, appalling to one visiting a spinning mill for the first time—a humming, steady clamour, as if each bobbin had become vocal, and, with ever-increasing vehemence, was crying out at being driven so fast. The amount of machinery packed on a mill floor is indescribable; it stands relatively closer than the type in this printed page. And the machines are all of the same build, as if made in a mould, all doing the same work, with here and there in the narrow gangways a girl or a man, whose duty it seems to be to watch them go.

But we cannot here linger on the various spinning operations in detail. There are many more things to be done before the thread is fit for sale. If it is to be white it has to be bleached; if it is to be coloured it has to be dyed. Let us go to the bleaching house, where inside a huge cylinder six feet across, and more than as many deep, a couple of men can be seen through the man-hole, packing the yarn much as if they were storing the hold of a ship. When the vat is full the air will be pumped out of it, and the 'chemic' will flow up into it from the tanks below. Another vat is full of yarn boiling under pressure. In another corner the yarn is being washed, knocked and beaten by wooden forge hammers. Close to us other yarn is being rinsed on square spindles that jerk it with a curious lap-lap motion as they turn it round and round, sunk to half its length in the water. Not far off yarn is being

blued in water almost as bright as that in the carboys of a druggist's window. And here is the hydro-extractor, in which the yarn is dried like clothes in a laundry, being thrown into a horizontal drum and spun round at lightning speed.

But all sewing cotton is not white. Some of it is coloured. Some of it? Yes; over eight hundred tints are required to suit the different markets! We are shown the pattern book. It is a severe test for colour blindness; and yet when the tints are arranged in order, how easy it is to detect the very slight difference between them! And now we enter the dye house and are among the coppers and the tubs, with men of many-coloured hands turning over square sticks, hanks upon hanks, of dripping, steaming cotton. First the mordant; then the dye. There are colours enough to satisfy a Turner. Here come a couple of men carrying between them a stick full of saffron looking like a thick massive fringe; and they are just passing a dripping heap of turquoise blue, with a gaudy purple beside it. Pinks and greens are prominent a few yards away, and by our side is a stack of dingy logwood red that with another dipping will become black, for most black thread has to be dyed logwood red at first.

But dyeing or bleaching is by no means the final process. As the thread had to be run off the bobbins to be dyed, it has to be run on again to be further dealt with. It has to be polished by a machine in which it is brushed till it shines, and it has to be wound and rewound until it is ready for the reel.

At last we reach the winding room, where the women sit some twenty deep in rank after rank by the side of the benches. In the first row the holes in the reels are being turned by revolving rasps, and the reels are in sacks by the side of the workwomen. Occasionally the reels split in the process, the original hole not having been bored straight. When the reel is true it is ready for the winding machine. In the nearest rows the women are attending to a reel at a time, the cotton running off the large bobbin on to the

reel, up and down with each layer, finishing when the reel is full, the end being fastened in the nick by the work-woman. But farther along we come to machines automatic in action, that are fed with reels, and wind eight at a time, and cut the nick and fasten off and throw out the full reel and catch up the empty one and wind it without any other attention than being kept supplied. And each of these machines requires but one attendant, and does a dozen times the work of the old pattern. Great are the triumphs of machinery; and great are the advantages of capital!

But thread is not always wound on wood. For export and other purposes it is wound upon cards; cards weigh less and take up less room than reels, and for short lengths are more handy. In another room we see the cards being wound. Side by side lie the cards, some twenty in a row, pointed towards the machine and spinning so fast that they look like reels. As they spin the girl fills in blank cards ready for the next turn. Almost before she has filled the row there is a click, and the bar of cards has turned a somersault, the full cards are motionless with the thread finished off, and the new cards are whirling round as if they had never known a rest. The full cards are swept off, empty ones take their places, and again there is a click and a reversal, and another batch is ready.

But the reels have to be labelled—an operation that does not take long. Here is a broad table, to which the full reels are brought in trays, every tray when full holding a certain number of each size. The girls take the labels from a pile, and swiftly stick them on to the reels, patting them down into position when the tray is complete. Another tray is put on the top, the reels are turned over, and their unlabelled ends exposed, and then the other little discs are dotted on to them and patted into place, and the reels are ready for packing, the contrivances for which are ingenious but readily conceivable.

And so we have got our 'vegetable compound,' the reel

of cotton. We have but hastily sketched the leading processes through which it had to pass; many blanks might have been filled up with advantage, but we have said enough to show that its story has not been uneventful. We can at least end appropriately and pleasantly by taking a lesson from our genial spinner, and wishing each other more cotton and less wood.

CHAPTER X.

PRINTING A COTTON GOWN.

A LARGE central cylinder round which the calico to be printed is gliding at the rate of, say, a cricket-pitch a minute. Round the roller is a layer or two of wrapping to give needful elasticity; and carrying the calico is a broad endless band. The frame of the machine branches out in starlike arms, and to every point of the star is fixed a system of two smaller rollers and a trough. The trough is full of thickish colour; the inner roller revolves in the colour, and distributes it over the printing roller, which in its turn presses against the gliding cloth.

Between the colour-roller and the calico is a thin strip of steel which scrapes the printing-roller free of cotton, except in the places where the pattern has been sunk. Years ago device after device was introduced to clear the roller from superfluous dye, but all failed. In a certain printing-works a new contrivance was being tried, and failing like the rest, when one of the printers took it in hand to adjust it properly.

'Ah,' said a companion, 'ye'll have to doctor it more than that.'

'Maybe,' said another, snatching up his dinner-knife and holding it against the roller so that the colour curled off with beautiful clearness. 'Doctor this and doctor that, but there's the true doctor for ye after all.'

And the sharp steel slip developed from that dinner-knife is called the 'doctor' to this day, though the Lancashire lad was anticipated by William Nicholson, who first used the steel straight-edge for the letter-press printing machine.

On the other side of the roller, so as to rub against it after the impression has been printed, is the 'lint doctor,' to wipe off all fluff and dirt that may have been taken up as the cloth was touched.

Surround the huge central cylinder with systems of these rollers; have twenty or even thirty of them if you like, but in a general way be satisfied with six or eight; fill each trough with a different bright colour, so that every pair of rollers is of a different hue, the outer line being in solid bars, the inner breaking the tint into spots, showing only where the pattern is incised; set the central mass in motion to quietly draw in the apparently endless plain white calico, zigzagging it over tension rails, and running it on, giving it an extra colour at every turn, until the last roller is passed and the printed strip vanishes overhead through a slit in the ceiling and ripples down another slit at the back of the machine dried and smooth, so that the printer can see how his work is progressing—and you have the calico printing machine.

But be not too hasty in your conclusions as to what goes on overhead. Between the points of disappearance and reappearance only a few feet of ceiling intervene—a ceiling over which is a chamber of mystery. The cost of the few feet out of sight would astonish you, until you enter the drying-room and find that the apparently few feet are hundreds of yards, and that before the cloth escapes it has passed up and down, up and down, through a long tortuous course of hot plate, hot roller, fixed frame, and rocking frame, to fit it for the printer's inspection.

Calico printing was brought from India by the Dutch East India Company, and first found its European home in Holland. The two ends of that old trade route have left their mark in the cotton trade till even now, for from Calicut came 'calico,' and from Holland came 'brown holland.' In 1676 there were calico printing works at holiday-loving Richmond on the Thames; sixty years afterwards the industry sprang up near Glasgow; and in 1764 it made its first start in Lancashire. At first the patterns were printed one colour at a time by wooden blocks, slabs of sycamore being cut, as box is to-day cut by wood engravers; and occasionally strips of copper were sunk on

edge as in modern brass-rule work, only the strips were kept in place by layers of felt. The next step was to print more than one colour at a time, and to help this came the 'toby,' a box in compartments, each compartment having its colour-pad fed by a bird-glass arrangement, so that one pressure of the many pads inked the block with many colours. There are some colours, even now, that cannot be printed on the rollers, and the parts of the pattern they are required for are still blocked in. In this block-printing, whether single-coloured, or multi-coloured, the continuance of the pattern is assured by the pin at each corner of the square block, the pins on the left-hand side fitting into the pin-holes left by the pins on the right-hand side where the previous impression was made. It was in 1783 that Thomas Bell, of Glasgow, took out a patent for a six-colour roller printing machine. Since then the advance has been entirely along the roller line; and so greatly have the rotary machines increased in this country that nearly a million miles of calico are now printed by them in a year.

Before it is printed the calico has to be bleached, and this bleaching is a trade of itself, being the third of the four trades through which the cotton gown has to pass. First, there is the spinner, who spins the bale of cotton into yarn; second, there is the weaver, who weaves the yarn into calico; third, there is the bleacher; fourth, there is the printer. And it is rare indeed that all four operations take place in one establishment.

The bleacher takes the newly-woven cloth and passes it over a hot roller kept at a red heat by the flame of a furnace passing through it as it spins; or, in the newest method, he passes it between two batteries of gas jets at the rate of 5,000 yards an hour, too fast for it to take fire, but slow enough to burn off the nap and leave the surface smooth. Piece after piece sewn together is thus passed through the fire in one long strip, and then, twisted into a rope, runs out through a hole in the wall, to be stowed in a huge vat known technically as a 'kier,' and be therein boiled with milk of lime or soda ash, or something else, to clear out the grease and wax. Then it is washed in water, and washed in weak acid, and washed in water again, and passed through

chloride of lime solution and treated with acid again, and so on, and so on, until it is thought to be sufficiently clean.

A hundred years ago 'bleaching powder,' otherwise chloride of lime, had not reached Lancashire; and the fields were white with the long strips of cloth hung out on lines and poles to bleach in the sun. Now more rapid measures reign, and the healthy out-of-door life of the bleacher has become a damp existence on the wet stone floors of gigantic wash-houses redolent of soap-suds and chlorine.

But clean as the cloth may come from the bleachers, it would not suit the printer to use it in its rough state. It has passed through the fire, it has passed through the water, and now it has to pass under the knife. One side of it is shorn, or rather planed, so that it now has a rough and smooth side. And it is the smooth side that faces the printing roller.

The roller is of copper, the width of the piece of calico, and about six inches thick. It is worth about £5. Every tint in a pattern requires a separate roller; say there are four colours in a pattern—a low average—each pattern means £20; multiply that by the thousands of patterns, and you have some idea of the capital locked up in copper at a calico printer's. So expensive are the rollers that when a pattern goes out of fashion it is cleaned off the roller; and so thinly is it cut in that a roller may see service a dozen times and more.

And now, how does the pattern get on to the roller? That is the most interesting part of cotton-printing. The men engaged in the work are a superior class. There is a wide gap between an ordinary mill-hand and a pattern-engraver. And the gap is more extensive than might be supposed. At Lockett's, in Manchester, for instance, over 400 men are employed, many of them having been with the firm all their working lives, and all of them pulling together on brotherly lines, with clubs and associations, sick-funds and fellowship-funds, such as are only found among the aristocracy of our artisans. There are working men and working men, and in no place is the distinction marked more sharply than in our cotton towns. The Lancashire lad is of two such well-marked species that

a trinomial nomenclature is needful in describing him. There is the lad who never loses a chance of picking up information that may be useful to him, who makes the most of the libraries and educational institutes in which the county is so rich, and is eager for science lectures and every intelligent form of amusement; and there is the lad who claims the streets as his warpath, and is the uncouthest specimen of humanity known to Britain. And as the lad is, so is the lass; on the one hand the healthy, cheery, but somewhat shrill, little person, whose home is a pattern of neatness; on the other the trolloping, thriftless, feather-hatted down-troddener, who can be seen cleaning her door-step at three o'clock on a Sunday afternoon. The politicians tell us these are not species, but varieties, and that one passes into the other; but those who have known Lancashire longest are beginning to bewail the links that have somehow gone a-missing, and might have served as rungs in a ladder to save those on whom the factory system is so unmistakably leaving its mark. The men and women have sunk to be 'hands,' and as hands they are content to remain.

But our business is with the pattern of the print, not with the pattern of the people. Through what steps does it pass before it reaches the 'doctor'?

In the first place, then, where does the design come from? It comes from Paris. Such is the fashion of the trade that no print will sell unless it is of Paris design. In woven goods, wherein the pattern is given in the loom, fashion decrees that the design must be of home-growth or adaptation; but in goods on which the pattern is printed, nothing short of Parisian will suit the crowd. At the same time, although the design must come from Paris, it does not follow that it originated there. In fact, it is rumoured—we must be cautious here, and so we will content ourselves with 'rumoured'—that, in these days of cheap postage and quick mails, an occasional pattern—only an occasional one, let our housemaids note—is drawn in a Lancashire street, and finds its way to the printers opposite through the hands of 'our energetic Paris agent.' In short, were it not for the senseless folly of the would-be genteel, foreign designs

would have been thrown overboard long ago. South Kensington has done splendid work with its limited means, and the designers trained in its schools in our manufacturing towns are quite equal to working for the nation, if only the nation would look at home for its fashions instead of seeking them where they did in the days of the Old Pretender.

When the design arrives direct from Paris—or from the next street by way of that celebrated capital—it reaches the engraver through the manufacturer or the printer, as the case may be, for sometimes one takes up the design, and sometimes the other. Then a tracing is made of it, so that it can be lengthened or shortened to suit exactly the dimensions of the copper rollers to which it is to be transferred. And in this alteration—for all patterns require some alteration—endeavour is made to do away with any sketchiness that may be avoidable. Sketchiness is the technical term for the tendency of patterns to show lines of spacing across the cloth in a way that is objectionable. In geometrical patterns the objection does not apply, for the lines are accentuated and made the most of; but in fancy and floral patterns it is held to be fatal if the patterns can be cut up into unbroken squares, diagonals, or parallels. Just as a wall-paper is badly designed if it has a tendency to tease the eye with an unintentional row of dots or patches, so is a printed calico; and in the majority of patterns as they reach the engraver, the insertion of a twig or a curl, or the very slightest shifting in relative position, leaves the thing much as it was, and at the same time makes it saleable.

The pattern, having been adjusted and improved, is then placed under a camera and enlarged from four to seven times, so that further faults may be corrected. It is then in its enlarged form carefully painted on a plate of zinc, which it is essential should be free from grain or impurity; and the zinc is then engraved. For every tint in the pattern a roller is required, and every roller requires one of these zinc plates, on which there is engraved only such part of the design as has to be printed in the one particular tint. Just as in chromo-lithography every colour has its stone, so in calico-printing every colour has its roller.

The carefully-engraved plate is then spread with putty and fixed in a pantagraph—which is a truly wonderful machine. In front is the plate of zinc, over every engraved line in which the tracer is to move. On the top is the bright copper roller, covered with a film of grease like an ordinary etching-plate. At the back is a row of diamond-pointed claws, each of which is moved by the tracer in front, the number being dependent on the number of times the pattern is to be repeated along the length of the roller. By an ingenious system of gauges, the pattern on the zinc plate can be reproduced on the roller the same size as on the approved tracing, and repeated just as many times as will completely cover the roller's circumference without giving any sign of a join. The combination of wheelwork and linkwork by which this is done is too complicated for description here; let it be sufficient for us to realize the tracer passing slowly along the lines of the plate, and the two dozen or more tiny claws all working on the roller at the same time as it slowly revolves, moving hither and thither, in and out and round about, backwards and forwards, in all directions, all together steadily and truly without a shake or sign of hesitation, as if they were a rank of liliputian infantry exercising on a path of gold.

At last the film of putty with which the flat plate was spread to show the tracer's progress is scored along every line. The roller is finished. Where the points have touched, the bare metal is left; on the rest of the roller the coating of grease is undisturbed. The roller is taken to a trough of nitric acid and revolved in it till the acid has bitten deeply enough into the exposed metal. And then it is cleaned and trimmed, and is ready for use.

But perhaps the design is too small for the claws of the pantagraph to tackle it? Then another process is resorted to. The pattern is engraved on softened steel in intaglio; in other words, a die is cut, which die has to be proportionate to the 'mill,' as the mill is to the copper roller. The die is hardened, and over it is rolled, under hydraulic pressure, a softened steel roller, until the impression on the die appears in relief on the roller. This small steel roller is then hardened and becomes the mill, which in its turn is

rolled on the copper roller, and transfers its impression in relief on to the copper in intaglio, and transfers it just as many times as will make the circuit complete. As with the pantagraph process, a roller has to be made for every colour in the pattern, and this means a mill and die for each.

Sometimes patterns are so simple that they can be punched direct on the copper, and by this method much time is saved. Sometimes new patterns are but certain combinations of stock devices, and then, as in pottery, the old stamps can be used, to the great saving of time and labour. Sometimes a wooden roller deftly cut will save a deal of trouble in engraving; and much of what is known as 'eccentric work' is done in this way. But the prettiest process of all is the pantagraphic one; and that is the commonest. The tiny fingers scratching so quietly and humanly the long cylinder of copper once seen will never be forgotten.

When the set of rollers is complete, proofs are taken, as in ordinary ink printing; and they are then fixed in the machine in due order and adjusted until the impressions fit —'register,' as it is called—as intended by the engraver.

But in calico-colouring there are many processes; and the style of printing we have described is but one, or part of one, of these.

There is a style in which mordants only are printed on the machine and the cloth is dyed afterwards; there is a style in which the cloth is dyed first and then a pattern printed on it which simply clears away the ground colour; there is a style where a 'resist' is printed on the blank cloth, the 'resist' being a substance that is unaffected by the dye, so that the calico can be dyed after the printing, then have the resist washed away, and perhaps have a colour printed in the places thus left blank; and there is the style in which the colour is printed directly on the cloth and fixed by being steamed; and some patterns require a combination of some or all of these processes.

The two chief dye substances are alizarin and indigo. Alizarin is the colouring matter of the madder-root. Twenty years ago a million pounds worth of madder came into this

country every year; now the value of the madder imported is but a few thousand pounds; for our alizarin is got not from the vegetable root, but from coal-tar, and costs but a quarter as much. Alizarin as we now know it is, chemically speaking, bioxyanthraquinone, or $C_{14}H_6O_2(OH)_2$, and its first synthetical construction from anthracene was one of the most brilliant feats of organic chemistry. It was known that there were bodies in coal-tar which belonged to the same class as alizarin, and the result of the researches of many chemists in all parts of the world was a simultaneous discovery. On the 25th of June, 1869, Caro, Graebe, and Liebermann obtained a patent for the manufacture of alizarin in Britain, and Perkin, of aniline fame, applied for a patent on the following day. Since then improvement has followed improvement, and now purer alizarin can be obtained from coal-tar than from the madder-plant. Even as far back as eight years ago there were 14,000 tons of alizarin produced in this country, and these are reckoned as being equal to 126,000 tons of madder. Alizarin is a very chameleon, and gives a different hue with every different exciting cause. Treat it with alumina and it becomes red, treat it with chromium and it becomes black, treat it with iron and it becomes chocolate, treat it with lime and it becomes violet, treat it with tin and it becomes orange. Print the patterns on the white cloth in colourless mordants, pass it—looking clear as if nothing had been done to it—through a vat of alizarin, and out it comes, as if from a magician's bath, aglow with as many colours as an Ogilvie tartan.

As madder has been supplanted by alizarin, so will indigo be supplanted by another 'in'—in fact, a process has been discovered, but cannot yet be worked cheaply enough to pay. Indigo is the best and fastest of our blue colours; it is the most widely used; and, when its chemical manufacture begins, the revolution in trade it will cause will be far more serious than when madder found its master. A curious industry is the making of vegetable indigo. The leaves and twigs are fermented in water until the indigo becomes deoxidized and dissolves; then the solution is run off and dashed into spray with oars, and the oxygen of the air

combines with the substance in solution, and the colourless soluble indigo becomes blue and insoluble by oxidation, and falls as a precipitate. The precipitate is exported in cubes, and ground to powder and mixed with copperas and lime. The lime decomposes the copperas and there is a formation of sulphate of lime and protoxide of iron; the protoxide absorbs the oxygen from the indigo and becomes peroxide; and the deoxidized and decolourized indigo dissolves in the lime-water, and we have the colourless dye. The white cloth is passed through and comes out colourless, but as it is exposed to the air it becomes bluer and bluer as the dissolved and colourless indigo again becomes oxidized, and firmly fixes itself in the fibre of the cloth.

But enough of dyeing. To mention all the dyes, aniline and otherwise, were here unreasonable, though we are loth to pass aniline black without a word of recognition. It was in 1860 that Lightfoot, in printing chloride of aniline from a copper roller, noticed that the colour darkened, and, thinking it might be from the mere trace of copper obtained from the roller as the colour touched it, he mixed a copper salt and oxidizing salt with the aniline chloride, and solved the problem of aniline black. Afterwards it was found that the oxidation could be more readily obtained by adding to each gallon of chloride two or three grains of vanadium (the rare metal found by Roscoe in the sandstone of Alderley Edge), and vanadium came into commerce, the printers being glad to get at six guineas an ounce what is now in the market at five shillings. But the romance of dyeing we must leave for a while.

We have seen the calico printed, and imagined it dyed, and it now has to be dried and aged. Ageing is to precipitate the mordants in the fibre of the cloth and partly decompose them; and in the new style it is done in what is practically a huge oven with many steam pipes and jets. In the old style it goes on in a much more leisurely manner in a lofty room over seventy feet high, the printed strips hanging in rows, as if it were washing day in a land of length without breadth. The floor of the room above is as full of traps and grooves as the stage of a theatre. To one of the slits a roll of print is taken and the end made fast;

above it is an iron trapeze that is lowered on to it, presses it, doubling it into the slit through the floor and downwards, while the length unrolls rapidly. Soon the trapeze reaches its limit, and ceases to fall, but the cloth thus helped comes down with its own weight with a shiver and a rush and a whistle as of silk, until it is but a few feet from the ground.

But when the cloth is duly aged, it is not thought fit for its struggles with the world without some preparation, and again it becomes a miserable rag, and undergoes many washings perhaps before it is blued and starched and mangled and calendered, and made presentable enough to pass muster. Then it finds its way to the folding-machine, through which it runs over a rocking-frame that in its swing covers just the yard into which the piece is measured as it falls. And then the yard-long bales are submitted to the mercies of the hydraulic-press, and make themselves small under very considerable pressure, and take unto themselves the form under which we know them in the draper's window as 'New season's prints, Paris designs, $5\frac{3}{4}d.$ per yard.' And, considering all they have been through, we are quite able to agree with the enterprising man of farthings that they are 'really wonderful at the price!'

CHAPTER XI.

THE CENTENARY OF THE ROTARY PRESS.

I.

WITH this 1890 the hundredth year will pass since machine printing, rotary printing, and printing by steam were first given to the world. Amongst the constantly growing crowd of centenaries and jubilees with which we are troubled it would be difficult to find one better worth remembrance. We are never weary of telling of the miles of paper that go roaring through the London presses in the small hours of the morning; but the true story of how it all came about seems to be little known. It is not to be found in the cautiously worded statements in encyclopædias and technical manuals; and it is only by much recent research among British and American specifications and other contemporary authorities that we have been enabled to correct errors of detail and date and supply missing links so as to realize the actual circumstances of the case. The story is not uninteresting, and it has much in it of what we are pleased to call human nature—the human nature tainted with meanness which we all profess to be so anxious to get rid of. In its way it is quite a stage drama, with its struggling inventor ruined by his own ingenuities, its middleman, and its tolerably honest second hero yielding to a sudden temptation and saving his reputation by an act of downright knavery, which he trusted never would be found out.

Some of us may be familiar with Nicholson's areometer;

many of us have read of the Count Beniovski, or Benyowski, and his remarkable adventures in Siberia, Madagascar, and elsewhere; and more of us have heard of the Royal Institution in Albemarle Street; but it may be news to learn that the inventor of the areometer, the translator of Beniovski's memoirs, the author of the Royal Institution prospectus, and the inventor of cylinder and rotary printing by steam were one and the same man. This was the William Nicholson who in his day did an immense amount of miscellaneous literary and scientific work, who, with Carlisle, discovered the electrical decomposition of water, and of whom the biographical dictionaries say: 'Wisely as he could decide questions involving the interests of others, he rarely was successful in undertakings of his own.'

He was the son of a solicitor, and was born in London in 1753. In early boyhood he was sent to school in Yorkshire, where he certainly did not waste his time. But, Fellow of the Royal Society as he afterwards became, the spirit of adventure was fervent in him, and nothing would suit him but to go to sea. So in 1769, when London was full of Wilkes and Liberty, the discovery of the 'torporific eel,' and the ravages of Hyder Ali—'India stock fell above 60 per cent. in a few days'—Nicholson, in his sixteenth year, shipped on board an East Indiaman, and in her he made three voyages out and home. Giving up the sea, he entered the service of Josiah Wedgwood, the Staffordshire potter, and by him was given an agency on the Continent for the sale of the well-known ware. But the charms of the pottery trade, like those of the sea, failed to satisfy him, and, leaving the Continent, he came to settle in Soho Square as the keeper of a mathematical academy and a writer of books.

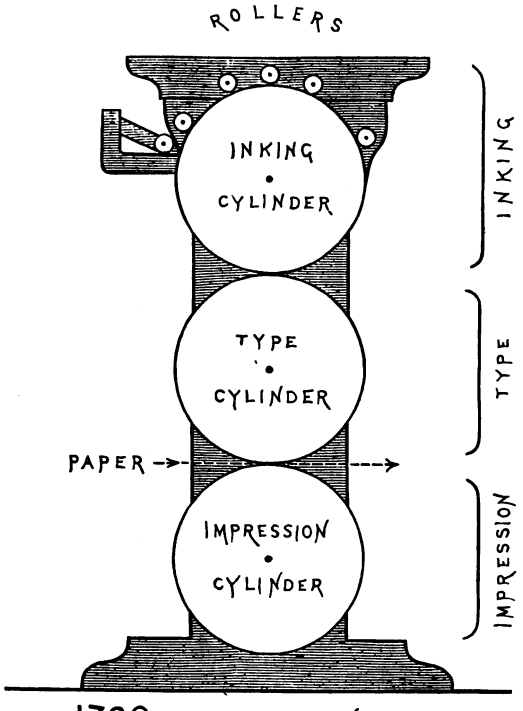
He translated, as we have said, the memoirs of Beniovski 'from the original MS.,' a translation which had the singular fate of being translated into Hungarian, that Beniovski's countrymen might for the first time read of their hero in their own tongue. He translated, also from the French, a *Life of Hyder Ali*, Chaptal's *Elements of Chemistry*, Fourcroy's *Elements of Natural History*, and

Venturi's *Experimental Inquiries Concerning Fluids.* He wrote a *Description of the Steam-engine* and *The English Mechanician,* which were translated into French; and he also wrote a *Description of London Public Buildings, The Art of Bleaching by Oxygenated Muriatic Acid,* a *First Principles of Chemistry,* an *Introduction to Natural Philosophy,* and a well-known *Dictionary of Chemistry* (which was the basis of Dr. Ure's); but he did not write *The Navigator's Assistant,* which was the work of a namesake of his at Chatham. In addition to all this, he projected and edited *Nicholson's Journal of Science,* which lasted for seventeen years; and in the first volume of this, at the conclusion of his description of his invention of the printing machine, he very neatly remarks that 'new undertakings are generally brought forward by the inventor—a man strongly prejudiced in favour of his leading pursuit—together with a moneyed friend, who hopes to speedily increase his capital from the abilities of the other.'

Among his patents is one for making files by machinery; another is for a steam blast, on the injection principle, for furnaces and stills. How he came to invent a printing machine we have not discovered; probably, as a writer of books, it was suggested to him by the difficulty experienced by his printer in keeping a promise with the existing machinery. All we know is that he set to work on it in December, 1789, and that on the 29th of April, 1790, he took out his patent. The specification was sealed on the 29th of May of that year. It is No. 1748, and it is printed, and can be found in its proper box in the Patent Library, or it can be bought for sevenpence at the Patent Office in Cursitor Street; or—and this is an important point in our story—it will be found in Vol. V., p. 145, of *The Repertory of Arts* for 1796.

Our illustration is from the drawing in the specification at the Patent Office. It will be seen that we have here three cylinders—one for the ink, one for the type, and one for the impression—an ink-trough, from which the roller at the end of the arm is lifted at every revolution, a series of distributing ink-rollers, and an entirely forward motion of the paper. In all these matters, remarkable as it may

seem, this patent is new. It is the first suggestion of the employment of a cylinder, or a segment of a cylinder, in typography, and the first suggestion of inking by roller;



1790 - PATENT No. 1748.

and the machine, so the specification says, can be driven 'by steam,' which is the first mention of the application of that new power to any method of printing.

The presses this one was designed to supersede were the

old wooden hand-presses, made on much the same principle as those in which we squeeze linen. The type was inked by being dabbed over with leather balls; it was laid flat on the bed of the press; the paper was laid flat on the type; the flat platen came down to give the impression; the power was got by means of a screw and a lever; and the paper was drawn out on the same side of the press as it went in at.

The patent covered the wide area of printing on paper, and fabrics, and floor-cloth. In type-printing, with which we are alone concerned, it showed how the type bodies could be shaped, like the stones of an arch, so as to fit into frames or chases adapted to the surface of a cylinder—which cylinder could be of wood, 'or metal,' another important suggestion. For the inking arrangement we may as well have the patentee's own words: 'I distribute or apply the ink by causing the surface of a cylinder smeared or wetted with the colouring matter to roll over or successively apply itself to the surfaces of the type, or, in short, I may also apply the type to the cylinder. . . . I apply two, three, or more small cylinders, called distributing rollers, longitudinally against the colouring cylinder, so that they may be turned by the motion of the latter; and the effect of this application is that every lump or mass of colour which may be redundant, or irregularly placed upon the face of the colouring cylinder, will be pressed, spread, partly taken up, and carried by the small rollers to the other parts of the colouring cylinder, so that the last will very speedily acquire and preserve an even face of colour.' Nay more, 'if the colour be very thin, I apply an even blunt edge of metal or wood, or other material, or a straight brush, or both, against the colouring cylinder, for the purpose of rendering its colour uniform.' What a step is this from the ball method! 'I perform all my impressions by the action of a cylinder. I cause the paper or material to be printed on to pass between two cylinders, or segments of cylinders, in equal motion, one of which has the assemblage of types on its face, and the other is faced with cloth or leather.' And the way in which this can be done is shown in the numerous drawings in the specification. We

have the machine all cylinders, as given in our illustration, and, what was then of greater practical value, we have a machine in which the wedge-shaped type is abandoned, but ordinary type is used in a flat chase, and the bed of the press travels backwards and forwards, the impression being given, be it understood, by a cylinder, or a segment of a cylinder, having grippers for taking the paper round and releasing it. In fact, we have not only the principle of the rotary press, but that of all the modern printing machines clearly set forth.

A noteworthy invention! But in this country it did not meet with success. Either it was before its time, or the inventor could not find or trust 'the moneyed friend hoping to increase his capital from the abilities of the other.' But though the patent hung fire in England, it had not escaped the keen eyes of the wideawake Yankee. Isaiah Thomas, of *The Spy*, the printer who set type at seven years old, who fought at Lexington, and sent Paul Revere on his midnight ride, wrote a history of printing in America. In the original edition of that excellent work, published at Worcester, U.S.A., in 1810, a copy of which is in the King's Library, we read that—'Some years since, Doctor Kinsley, of Connecticut, who possessed great mechanical ingenuity'—he invented a pin-making machine and a brick-making machine—'produced among other inventions a model of a cylindrical letter-press. It was a subject of much conversation among printers, but was never brought into use. The invention, however, did not originate with Kinsley. Cylindrical letter-presses were invented in 1789 by William Nicholson, of London, who obtained a patent for them in 1790. Kinsley's model was from Nicholson's plan with some variation. Nicholson placed his formes of type horizontally; Kinsley placed his perpendicularly; his method was not calculated for neat printing. Nicholson's presses were used, and, it is said, made excellent work. These presses require but one person to work them, who is able to perform as much and more work in a day than two common presses. The workman applies a sheet of paper to the forme, turns the cylinder by a handle, the impression is made, and he has nothing more to do than

to take off the printed sheet and put on another white one, thus continuing to print. The forme is blacked by the revolution of rollers properly prepared for the purpose.'

The 'Doctor Kinsley' was Apollos Kinsley. He patented his 'cylindrical letter-press;' and the 'some years' was sixteen years, the date of the patent being 16th November, 1796. The specification did not pass unnoticed. Not long afterwards there came the wheel-press of Benjamin Dearborn; on 1st February, 1810, there was patented Sawin and Wait's 'circular printing machine;' on the 28th January, 1811, Sawin and Wait patented their 'cylindrical press;' and then came other inventions on Nicholsonian lines.

Meanwhile Nicholson had sunk into difficulties, 'owing to his many unremunerative inventions,' and been lodged in the King's Bench. And here we can drop the curtain on the first part of our story, in which we have had the invention of the machine, its neglect in this country, its appropriation by the Americans, and the ruined inventor in prison for debt.

The second part begins at Luther's town, Eisleben, in Saxony, where Friedrich Koenig was born in 1775. There in his little printing office, in 1806, Koenig and his friend Bauer were at work on the problem of how to print by steam. The problem as it presented itself to them was: Given the flat type and the flat platen, how are we to ink the type and bring down the platen on it so as to get just enough power and dwell, and no more? For years they had been at work, and at last they had found something which they thought 'would do.' But no German capitalist would hear of steam printing, nor would any Russian, as Koenig found on journeying to St. Petersburg; and as a last resource they resolved to try London. To London they came, and in Thomas Bensley, a prosperous printer of the day, they found their friend and capitalist. The machine they suggested seemed to him impossible, but he saw in it the promise of something better, and Koenig started to try again—this time at Bensley's expense. In 1810 the new machine was within sight. It was on the old principle of

the platen and the flat chase, but it had the inking cylinders which had been introduced into printing by Earl Stanhope for his well-known hand-press, and, in 1807, patented by Brown.

The planning of the machine had been kept secret; to patent it the secret must be revealed. What was the best thing to be done? 'Oh!' said a friend of Bensley, in reply to a general inquiry about patents, 'want to know about patents? There's old Nicholson, in the King's Bench; he has had patenting enough—he ought to be able to give you a hint or two!' And, knowing nothing of the Nicholson proposal of 1790, off went Bensley and Koenig to interview the penniless man. They told him the nature of their invention. 'Why!' said Nicholson, 'I solved the problem twenty years ago!' 'You did?' said Bensley, aghast. 'Yes, and patented it. You will see it in the fifth volume of *The Repertory of Arts.*' Bensley was 'staggered,' Koenig 'could not believe it to be true,' and off they went abruptly 'to the nearest public library,' and looked up *The Repertory*, and read the specification. 'I thought it nonsense,' said Bensley, 'and could not wade through it!' 'I read it through,' said Koenig afterwards, in his published statement, 'but after a few days I had forgotten Mr. Nicholson and his project!'

Bensley and Koenig saw Nicholson no more. They patented their invention the 29th of March: its specification, No. 3321, boldly begins, 'A is a press with a plattin, as in other presses.' Nicholson sent them in a bill for the interview, and they paid it. In April, 1811, more than twelve months afterwards, they managed to print something on the machine they had made: the job was sheet H of the *Annual Register* for 1810. Of this sheet, 3,000 copies were thrown off.

But that was all the machine could do. It was never used again. It was a failure. Koenig was sorely pressed; he was on the verge of ruin; he had been on the wrong scent entirely; the platen was impossible. Why not try Nicholson's impression cylinder? Nicholson was old, and poor, and friendless, and could do nothing; besides, it was only an idea, and anybody might have an idea! Why

should he not have one? And he did—the same idea, in fact; and he took it without a word of acknowledgment; and he even continued to claim it for his own, when he was at length asked for his answer. 'Were you not aware of what Nicholson had done?' asked Cowper. 'Sir,' said Koenig, 'I made a point of not reading anything that other persons had done, in order that the machine might be entirely my own invention.' 'But,' said some one, later on, 'you had read the specification and seen the drawings?' 'Yes, I did read it; yes, but it was not worth remembering, and the cylinder is my own invention, sir! And at the same time it had already been attempted by others without the desired effect!'

The platen was abandoned; the cylinder took its place; the machine was built, and it was a success. It was patented on October 30th, 1811, No. 3496. In the specification, 'A is a press with a plattin' was now replaced by 'B is the printing cylinder.' It was completed on December 12th following, and by it there were printed sheets G and X of Clarkson's *Life of Penn*,—the first sheets printed with an entirely cylindrical press—the papers of the *Protestant Union*, and sheet M of Aiton's *Hortus Kewensis*.

The machine was brought to the notice of John Walter the Second, the inventor of the 'leading article,' who was then sharing the ownership of the *Times* with his father. Walter had been thinking of such an invention for years. He had applied to Marc Isambard Brunel, of block-making machinery fame, to help him; but Brunel had not seen his way to solve the problem. In 1804 one of his own compositors, Thomas Martyn, had devised some such machine, when the pressmen had revolted and smashed it. But Walter was not a man to accept defeat from those he employed, or discredit a principle because an example had failed; and soon he had another reason for looking about him. At the end of May, 1810, his pressmen went out for higher wages, and his compositors struck, not only for higher wages, but against the use of a new type then being introduced. The strike took place on a Saturday. Walter, with a scratch team, had a day before him in which to print his next issue, and, to the surprise of the strikers, the paper

appeared as usual on the Monday. The men were savage and revengeful, and for months the pickets kept the new workmen in peril of their lives, until in November twenty-one of the most violent were put on trial for conspiracy, and nineteen were found guilty.

Once again did a strike perform its useful function in improving machinery. Walter was only too glad to look at anything which lessened manual labour. He accepted Bensley and Koenig's invitation to see the press at work in Frith Street, Soho; he thought there were good points in the German machine, and, knowing nothing of the Nicholson episode, or Sawin and Wait, he delighted the partners by giving them an order. A new press with improvements was put in hand. Koenig and his friend Bauer were at work on it for three years in a building adjoining the *Times* office. Once, a significant anecdote tells us, they found the difficulties insuperable—the Nicholsonian notion was a delusion, then, after all?—and, disheartened, they slunk away, and no one knew what had become of them. But when they were sought out and brought back in three days, they found that John Walter had taken the matter in hand for himself and overcome the obstacle. Another patent was obtained—that of the 23rd of July, 1813, No. 3725. In it Koenig not only appropriated the cylinder, but also, by a similar process of unconscious cerebration, 'the principle of affixing a board or any straight body against a cylinder for the purpose of spreading the ink,' so that the machine had now the impression cylinder, the inking rollers, the straight-edge, and the travelling table of 1790. The work progressed in secret all the time, for Walter was mindful of Martyn's fate. On Tuesday, the 29th of November, 1814, at six o'clock in the morning, the pressmen of the *Times*, who had been kept waiting on pretence that late news was expected from the Continent, were astounded to see him enter with the day's paper already printed. 'It has been printed by steam in the adjoining apartment,' said he. 'I shall not want you any more. If any of you are violent, I have force at hand to suppress you; if you are peaceable, your wages shall be continued till you get another situation.'

Six months afterwards, on the 21st of May, 1815, Nicholson died in Charlotte Street, Bloomsbury. 'He made no claim,' said the *Times*, ten years afterwards—that is, as far as they knew. But, broken and dying 'in great poverty,' he was hardly in a position to make a claim with success, even if he had had an opportunity in prison of reading the new specification. The Koenig's patent on which he had been consulted was that of a platen machine, and this *Times* affair was built in secret, so that he only had the last half dozen months of his life in which to learn, from hearsay, that the new machine was no more like the old than chalk is like cheese.

Koenig was triumphant, but his triumph did not last long. He set to work on a machine for Bensley that would print both sides at once, and he patented it on Christmas Eve, 1814, No. 3868. It was a mere double of his single machine. But notwithstanding a florid prospectus in the best Barnumese, it proved to be too cumbrous to be saleable, and a quarrel broke out between the inventor and the middleman. There were recriminations; the cylinder was as much one's as the other's, and finally the capitalist took to advertising *Bensley's* machine! And in less than two years from that November triumph in Printing House Square Koenig shook the English dust from his feet and went back to Germany. With the *Times* machine he had run dry of ideas; he produced nothing else worth mentioning; and, as there were swarms of inventors and adapters all alive to the new condition of things, the march of invention soon left him by the wayside making money in Bavaria.

When he left the *Times* Augustus Applegath took his place. To Applegath printing owes much. He had a fine field for experiment, and he availed himself of his position to introduce every new idea he thought workable. The consequence was that in a very short time Koenig's machines were so improved that their own builder would not have known them. With Applegath was associated his brother-in-law, Edward Cowper. In 1812 Cowper and Applegath were in partnership as printers, printing tracts for the Religious Tract Society in Nelson Square, Great Surrey

Street. On the 9th of July, 1816, Edward Cowper, then calling himself 'ironmonger and mechanist,' of Newington Butts, took out the first patent for curved stereotype plates. The description of his method is briefly as follows: 'A mould is taken in plaster-of-paris, and a plate cast in the usual way. The plate is then heated equally either by placing it in an oven, or over a charcoal fire, or immersing it in boiling oil, or by any other convenient method. The plate is then laid on a level board, with the face downwards, interposing between the plate and the board some soft substance—three or four folds of flannel will answer the purpose. The board, the flannel, and the heated plate thus arranged are passed together between two cylinders—a common rolling press will answer the purpose.'

A very different man was Cowper to Koenig. At the close of his specification he says: 'As the method of printing by means of cylinders has been known some time, I claim no exclusive right to the use of cylinders as cylinders, nor for inking or colouring by means of rollers as rollers; but I claim the bending or curving stereotype plates, and printing with the same, paper never having heretofore been printed with curved stereotyped plates.'

On the 5th of March, 1818, Cowper, now calling himself 'a printer,' took out another patent, this time witnessed, strangely enough, by Bensley, in which his new perfecting machine was fitted with the distributing-table and 'end motion' of the composition inking-rollers. In 1815 Forster had found the Staffordshire potters dabbing on their patterns with lumps of glue and treacle. He took the mixture and made it into inking-balls. So said Forster. But Edward Dyas, printer and parish clerk of Madeley, in Shropshire, had another story to tell. Once upon a time, in his hurry, he had upset a glue-pot he had been using; and so intent was he on his work that he could not find his inking-ball, and in reaching out for it he seized the semi-liquid glue and with it inked a forme. So pleased was he with the result that henceforth 'he used no other.' And a completer and more doubtful version tells us how the same absent-minded Dyas popped the glue he was using into the treacle he was having for tea, and so discovered the

advantage of combining the softening influence of the saccharine with the resiliency of the colloid. Whether it be Forster or Dyas matters little: enough that it was Cowper who stuck the glue and treacle round a core and gave us the composition roller.

So many were the improvements and additions, that in 1827 the much-altered Koenigs were removed from the *Times* office, and new four-cylinder machines took their place. Twenty-one years afterwards Applegath reinforced these by the two monster machines with vertical cylinders, which we may regard as closing the first era of newspaper printing by steam.

II.

Any one who has spent a night in a newspaper office will have realized how vital speed is to journalism. In the small hours of the morning, when the last speech is coming in on relays of flimsy telegrams, and the compositors are working short 'takes' of half a dozen lines apiece, perhaps every one of this one speech; all on the rush, so that the fingers peck at the cases as if the types were alive and fighting in the boxes, and 'the man in the opening'—that is, the one behindhand with his instalment—is having a life led him to hurry up; then indeed is apparent the need of speed, for the newspaper train waits for no man, and no matter how late the speech may end, the race against time must always be won.

Few people outside the ring have a notion of how a daily newspaper is made, or how the 300 men on its staff find employment. Of the seventy compositors—'Seventy!' the reader interrupts. 'What can they find to do?'

Let us take an ordinary copy of the *Times*, and disregarding all previous estimates, which are mostly exaggerated, count it up for ourselves. Here is to-day's paper, an ordinary one, and a very unfavourable one for our purposes, owing to the space occupied by a celebrated case. It consists of

two sheets each of eight pages, each page of six columns. Of the ninety-six columns sixty-one are news, and the remainder mostly solidly printed advertisements, 1,264 in number. The columns one upon the other would measure fifty-eight yards over all. If the matter had been printed in book form, in the same type, it would have made a volume of 384 pages. It contains 200,000 words, and the million letters with which they have been set would extend side by side for close upon a mile. Even an ordinary penny daily will have its 750,000 letters, to say nothing of the leads and spaces; and at least half of these have to be manipulated between six o'clock in the afternoon and one o'clock in the morning.

The *Times* is an unfortunate illustration perhaps, as for years the greater portion of it has been set by machinery, the ordinary notion of printing—a man sitting at a piano and rippling out types—having been long realized in that office regardless of expense. Nearly all the paper except the advertisements is now set by Kastenbein machines, as improved by the late Mr. Macdonald; and in fact not a little of the paper's unpopularity among 'the trade' is due to its being a non-society office, and 'employing machinery to do the work of men.' The *Times* has a telephone connected with the Houses of Parliament. The shorthand notes are read off at Westminster through it, and the messages are dictated to the type-setters. Later in the night the original transcript of the shorthand writer is received, and the proofs are read by it, so as to check the telephonic dictation. The machine works at great speed, and sets a column of solid matter in an hour. All its disadvantages are made the most of by outsiders, and it is no secret that the Partingtonian broom has been at work for years endeavouring to keep out the machine-type-setting sea.

Besides the Kastenbein there are at least half a dozen successful patterns of these mechanical compositors without souls. There are the Mackie, the Swedish Lagerman, and the American Mergenthaler, now better known as the Linotype. There is the Fraser, which set 10,000 pages of the *Encyclopædia Britannica*, and for book-work is in such

growing demand. There is the Hattersley, which is at work on the Liverpool papers and at Sheffield. And there is that ingenious nicked-type machine the Thorne, now used on the *Manchester Guardian*, a single apparatus which both distributes and composes, the types going in at one end and coming out set up at the other, requiring only to be 'justified.'

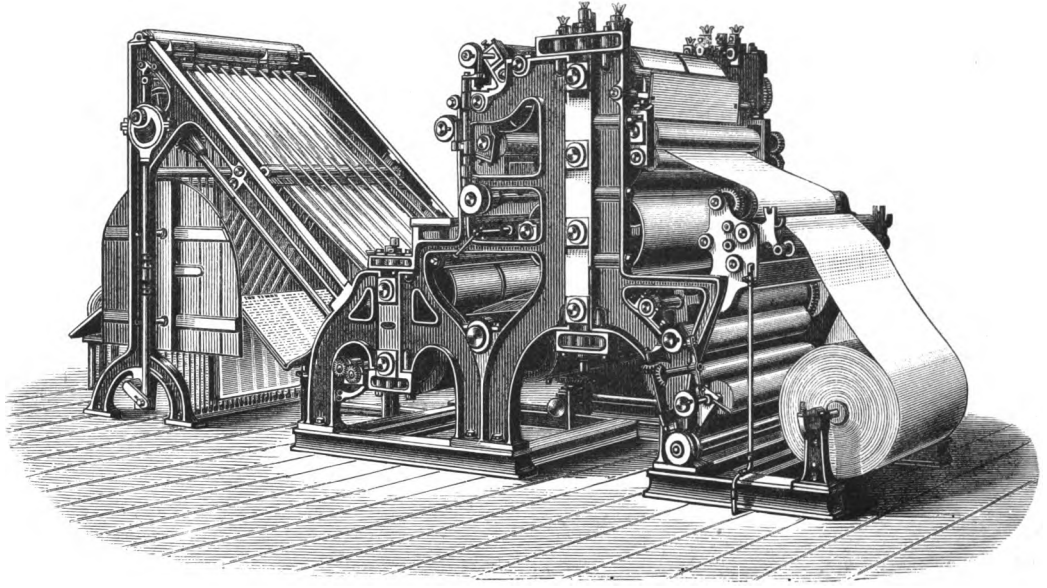
But the bulk of our journals are set by hand; and busily go the hands at half-past one in the morning. About two o'clock the last page reaches 'the foundry' to be stereotyped. Stereotyping is an old device. Van der Mey used to solder the bottoms of common type together, and make a stereo in that fashion. Ged, the Scotchman, began the new style; Andrew Wilson introduced the plaster-of-paris method; Cowper had, of course, something to say in the matter; but stereotyping was useless for rotary purposes until Dellagana's papier-maché process appeared. In fact, there has been no part of the present system of printing which has not been of gradual development.

'On asking,' says Mr. Herbert Spencer of the Walter machine, 'not what is its proximate, but what is the remote origin, the reader finds in the first place that this automatic printing machine is lineally descended from other automatic machines which have undergone successive development, each presupposing others that went before; without cylinder printing machines long previously used and improved, there would have been no Walter press. He inquires a step further, and discovers that this last improvement became possible only by the help of papier-maché stereotype, which, first employed for making flat plates, afforded the possibility of making cylindrical plates. And tracing this back, he finds that plaster-of-paris stereotyping came before it, and that there was another process before that. Again, he learns that this highest form of automatic printing, like the many less developed forms preceding it, depended for its practicability on the introduction of rollers for distributing ink instead of the hand implements used by printers' devils fifty years ago; which rollers, again, could never have been made fit for their present purposes without the discovery of that curious elastic

compound out of which they are cast. And then, on tracing the more remote antecedents, he finds an ancestry of hand-printing presses, which through generations had been successively improved.'

Applegath's vertical cylinder had a creditable life, but a short one. In 1848 a Paris newspaper, *La Patrie*, received a 'Lightning Press' from America. This was the invention of Richard Hoe. Hoe's father was a Leicestershire carpenter who had emigrated to the States, and become the brother-in-law of Peter Smith, whose hand-press is well known. Associated with Smith, he had turned his attention to press building in general. His son Richard was a man of many inventions. He invented placing the type on a fixed cylinder, and making the cylinders that give the impression travel round it; then he put the type on a revolving cylinder, and kept the impression cylinders in fixed positions. This was the Lightning Press. The Planetarium, as Hoe's first rotary press was called, was patented —his third patent—on 30th July, 1844.

In 1855 a second Lightning machine crossed the Atlantic, this time to London, to print *Lloyd's News*. Its superiority for newspaper work was at once acknowledged. Two similar machines were ordered for the *Times*, on condition that the workmanship of the new Lightnings was not so flashy; and to ensure the best of workmanship it was arranged that they should be made at Whitworth's of Manchester, then reputed to be the most accurate mechanics in the world. A somewhat amusing story is told of Whitworthian exactness. When the first machine was being erected Hoe's representative found that one of the spindles was a little too tight, and he sent it back to the shop with a request for 'a shade' to be taken off it. Up came Whitworth's highly scientific foreman to tell the American that in their shop they did not work to 'shades,' but to measurement. 'If you will tell us what you want in decimals, we will do it, but we will have none of your harum-scarum shades!' 'Oh!' said the Yankee, 'there, there's that sheet of paper; take that away with you and decimal up its thickness, and take off whatever your measures make it.' But until plans are drawn in which



THE WALTER PRESS

lines have length without breadth there can be an excess of accuracy, as is proved in this case. For when the machines were set to work in London they would not run. Everything fitted so exactly that nothing would turn round. There was hardly an allowance for air between the working surfaces, let alone a lubricant; and the spindles had to be eased, more or less undecimally, before a sheet could be printed. Then all went well, and the men of measurement and the men of shades shook hands.

For fifteen years the Hoes were supreme in the newspaper world. They were big, busy-looking complications, with a range of platforms on each side, a large central cylinder, a smaller impression cylinder for each platform, and a pile of flyers one above the other stroking down the sheets as they came shivering from each of the deliveries. The flat slab of type had gone; the type had now found its way round a cylinder; this cylinder in its revolution worked against from four to ten other cylinders, round each of which separately the sheets were fed and printed, so that every shelf did its own work. With ten platforms, though only one side could be printed at a time, an output of 8,000 copies per hour could be obtained. At first it took twenty-five men to work it, but with the addition of the 'flyers' —the waving gridirons that are so conspicuous in printing machinery—this number was reduced, the press then requiring the services of a man on each shelf, ten in all, as feeders, and four as removers, while two more were required to attend to the folding. Counting the overseer, we have thus a staff of nineteen, and an average output of 420 copies per hour per man.

But there is no finality in machinery. About 1860 the process of printing from stereotype was first brought to perfection; and in 1862 a machine-shop was set up in the *Times* office, wherein Macdonald and Calverley began the building of the press named after the chief proprietor of that famous newspaper. With the Walter rotary, which replaced the Lightning in 1866, it became possible with an overseer and six unskilled hands to keep two machines going, each at the rate of 11,000 an hour, including

stoppages, thus making the output 3,140 copies per hour per man.

The Walter owed its superiority to its printing from stereotype instead of from the 'movable' type, and using paper in a continuous piece instead of cut up into separate sheets. The curving of the stereotype had been thought of by Cowper, but the difficulty was how to do it, his own plan not working satisfactorily. He also had thought of printing from the roll, but there had been difficulties in the way, not the least of which was the opposition of the Revenue authorities, who preferred to levy the duty on reams composed of so many sheets. It was only when the paper duty was repealed that printing from the reel had a fair chance—another instance of how taxation may choke a trade.

Printing from continuous paper is known as 'web-printing,' 'roll-printing' or 'reel-printing.' Cowper was not the only one who had thought of it; but though the breath of inspiration does not always come from the Patent Office, it very often does so, and it is curious to note how that same mystic breath crosses and recrosses the Atlantic. Fifty-three years ago an American made a machine to print a duodecimo *Robinson Crusoe* from the *strip*. Forty-three years ago Applegath proposed to print from the *reel*. Thirty years ago a firm at Buffalo secured a patent for 'printing from a *continuous piece of paper*.' The jurors of our 1862 Exhibition reported that 'the course of the sheet in laying on at the Hoe machine is as direct as it can be made, short of printing from a continuous *web*.' Evidently web printing was in the air. On April 14th, 1863, a few months afterwards, William Bullock, of Pittsburg, Pennsylvania, patented his rotary machine 'to print from a continuous *roll*.' Some of the Bullock machines crossed to this country, and were worked to print the *Field* and other papers. In some quarters the Walter is claimed to be but a development of the Bullock; just as in others it is said to come from the Beach or Double Hoe.

Be this as it may—and it probably is untrue—the Walter takes us back even nearer to Nicholson than did the

Lightning. The Lightning had the central type cylinder and the girdle of smaller impression cylinders; the Walter has a printing cylinder and an impression cylinder both of the same size. But in the Walter the parts are duplicated, so as to print both sides instead of only one. At the bottom is a type cylinder with inking rollers

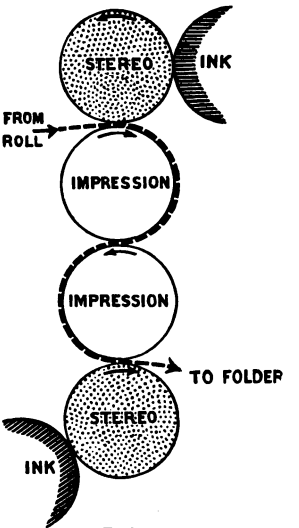


FIG. I.
WALTER.

alongside; above this is an impression cylinder which the paper runs under; above that is another impression cylinder which the paper in reversal runs over; above that is another type cylinder with the inking arrangement; the cylinders be it understood, being all four of the same size.

The reel of paper is long enough to stretch from Battersea

Park to Bethnal Green. It weighs 800 lb., and is sufficient for over 10,000 eight-page sheets of the newspaper. As it enters the machine it passes over a tension roller, and then if it has not been damped in the reel, it goes over and under two steam damping cylinders; then it passes between two small rollers to steady it and save it from dragging; and then it runs over the upper impression cylinder, being printed on its upper side as it passes under the type cylinder above it. Travelling round the impression cylinder it is taken by its printed side round the lower impression cylinder and receives its second printing as it passes over the lower type cylinder below. As it passes round the lower impression cylinder the inked surface leaves more or less of a mark, and to prevent this being transferred to the paper again a drum of the same diameter as the impression cylinder removes the ink, which is thus accumulated on the blanket, and this drum is then cleaned by a small absorbent roller. From the lower type cylinder the paper runs between two cutting cylinders, where the saw-edged knife in one of the cylinders perforates the web, which is almost immediately torn apart by two sets of rapidly-running tapes, one set of which travels faster than the other. The separate sheets are then taken down into the folding machine, from which the papers are delivered ready for sale. Such is the Walter press as used to-day to print the *Times*, and, curiously enough, its present active antagonist, the *Daily News*, and many others of the successful papers in the provinces and on the Continent.

For a time it was the king of printing machines. But inventors were soon at work endeavouring to equal it. In full swing it runs off 12,000 an hour, and to get this 12,000 an hour in a somewhat similar way without unduly trespassing on the few new details that had proved patentable was the object of the rival printing-press engineers.

At first the Walter delivered its papers unfolded. Here was the first opening. In 1870 the Victory came out, which not only delivers its papers folded, but counts them and delivers them in dozens or what not. The Victory is

a favourite machine with country papers, all of which can be identified by the peculiar folding. Take up one of these papers, and you will find it folded in such a way that you have to open the first and last pages right out before you can get at the middle. The fold has its advantages, but the advantages are not at first apparent to the man in a hurry. In the Victory—at least in some forms—the paper after being damped passes between two rollers and over a board, so as to smooth it before it touches the type.

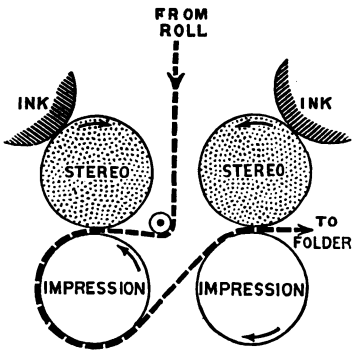


FIG. 2.

VICTORY.

The type cylinders are side by side with the impression cylinders below them, all four being of the same size. The paper runs along the top of the machine and then descends almost perpendicularly into it between the type cylinders. It runs backwards towards the reel to begin with, and is printed on one side as it passes round the impression cylinder; then it rises to the upper surface of the second impression cylinder and is printed on the other side, and then it is cut lengthwise, folded once, cut crosswise, and then in separate sheets is dealt with by the folding

apparatus, which delivers it along what looks like a series of desks on each side. In full career it can turn out 12,000 copies of an eight-page paper, or 24,000 copies of a four-page paper, per hour.

Close on the heels of the Victory, of which there are over 160 examples in use, came the Prestonian, with movable type in a curved chase, which movable soon gave place to stereo. The Prestonian, which was introduced into London by the *Standard*, had a capital folding arrangement, and

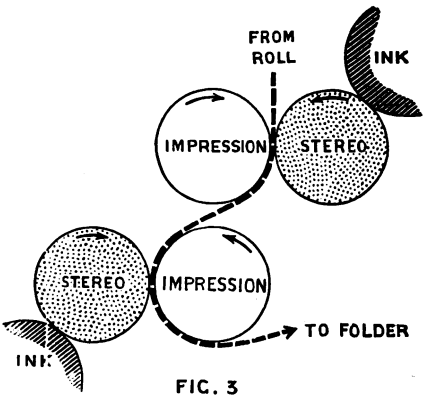


FIG. 3

PRESTONIAN

this arrangement fitted to the *Daily News* machines gave the Walter press its present form. Of Prestonians, more or less improved, there are now about two dozen printing London newspapers. In them the impression cylinders are over each other, and the type cylinders are alongside them, but on opposite sides, the upper one being near the folders. The paper from a reel in the rear is led up over the machine, entering it perpendicularly about the centre, passing at once round the upper impression cylinder and getting printed; then it passes towards the rear over the

under impression cylinder, and is printed on the other side; and then it travels along the base of the machine beneath the impression cylinders into the folder.

Two years after the Prestonian, that is in 1873, came the Marinoni web, which has its cylinders arranged as in the Walter, but with the inkers at the top and bottom. It need not detain us, for soon afterwards a more important new Hoe machine appeared in the market, which at once regained the lead that had for a time been held by the Walter. And now a much improved Hoe has appeared, the Quadruple, which we may look upon as the leading rotary press of 1890. This machine prints from two rolls instead of one, and consequently gives twice the speed or twice the quantity of the early rotaries. It weighs over fifty tons and is built up of about 6,500 parts. It prints and delivers folded a sixteen-page paper at the rate of 24,000 copies an hour, and an eight-page paper at a rate of 48,000 an hour; and these copies are not only delivered folded, but are pasted together down the centre margins as if they were pamphlets, and counted out in dozens, quires, or any batches required. It is now nearly forty years since the first Lightning machine built in this country began to print *Lloyd's News*, and *Lloyd's News* is now being printed on the *Daily Chronicle* Quadruples. It was the late Mr. Lloyd, of the *Daily Chronicle*, who ran the first of the Hoe web machines, in 1873; and it was Mr. Lloyd who had the first of these new Quadruples at work on a London daily newspaper. The *Chronicle*, like the *Daily Telegraph*, has always been a Hoe house, and both papers are now changing their machines for new ones as fast as they can be built.

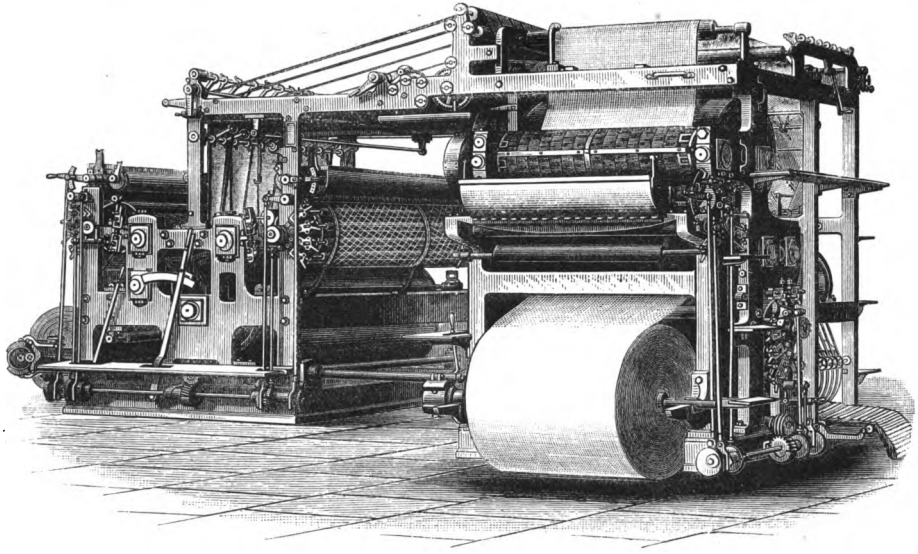
There are now over 700 Hoe machines at work in the newspaper offices of both hemispheres, the greatest power being in the *Chronicle* machine-room, where the output is a quarter of a million sixteen-page papers per hour. Most of the presses are made in New York, in a factory which is 1,350 feet long, 100 feet wide, and from five to seven floors high, giving an area of five acres and a half; but all the English machines are made throughout at the works in Mansfield Street, so familiar to what Mr. Sam

Gerridge denominated 'the nobility and gentry of the Borough Road.' Here can be seen the patterns being made for the castings; the tools making tools to make tools to cut and bore the frames and gearing; the turning and the planing, and fitting and erecting; and, in short, the complete growth of a rotary from the drawing-office to the trial run. And here is accommodation for the building of six of the largest machines at the same time. Here they are built and tried, and then taken to pieces to be built again in the newspaper machine-room.

But we left our newspaper as it left the composing room; let us follow it further. When the type reaches the foundry it is in flat chases, as it used to be of old. The stereotyper lightly oils it and lays a sheet of 'flong,' upon it. The flong is a pasty mass made by pasting together a few sheets of tissue, blotting, and brown paper. It is beaten into the type with a long-handled brush, or else rolled into it with an indiarubber roller. In this way a mould is taken of the whole area of type, and the mould is dried and placed in a casting-box, whose radius is the same as that of the printing cylinder. The box rests on its side in a frame, and its lid is balanced with a counterweight. A ladleful of stereo-metal—lead and antimony and 'something else'—is taken from the melting pot and poured into the narrow mouth which extends all along the drum. Soon the mould is full and the metal runs over. It does not take long to cool. The lid is swung up; the bright casting is at once attacked by a saw and plane that trim its edges, and in a few minutes is in its place on the printing cylinder. In a quarter of an hour from the time of leaving the composing-room the castings will be fitted on the machine.

The machine is ready to start. We are to print a sixteen-page paper in duplicate on the new Quadruple Hoe. Both rolls, each double the width of the paper when open, have been rewound from the maker's roll and examined and damped in the reeling. They are each over six miles long, and have been threaded into place through the machine.

The word is given to go. A pull is applied to the levers



THE HOE QUADRUPLE PRESS.

as if we are starting the engine of an Atlantic liner. Slowly the wheels and drums begin to move, but every revolution is faster, and soon they are fully under way, and the wheels hum and the drums roar as the white stream seethes among them, and the folded journals throb feathering out at the end at the rate of 200 every half-minute, being 24,000 an hour!

Watch the course of the main roll. It gets to business at once on top of the impression cylinder, takes the type, passes under the second impression cylinder (which is double the size of the other, so as to minimize the set-off), runs up the further side of it, gets its second printing and hurries aloft into the folding frame. As it enters, it is cut longitudinally, and the two halves are turned outwards at half a right angle, and then turned inwards again, so that one runs under the other.

Now watch the side roll. That also is printed first on one side, then on the other. That also finds its way aloft, to be cut longitudinally. That also is turned outwards and inwards. But it is also turned away at a right angle, and in two halves, one above the other, slips in between the two halves of the main roll, so that four streams are travelling in parallel planes. The inner two have passed over a small disc revolving in a paste trough; and down the centre of each is a wet line like the track of a snail. Soon the two upper and the two lower approach one another. They bend right and left. Their centres run over a former—a broad, smooth, sloping shelf of steel, in shape an equilateral triangle. The vertex of the triangle is a steel point worked by a stubborn spring. The point comes just in the centre of the paper, which droops on each side and folds downwards into half as it passes over it. As soon as the crease is complete the paper is again in trouble; it reaches a pair of cylinders carrying a double set of knives, which fold its end and cut the web just where the end comes, while the blades on the opposite cylinders crease the paper across the middle of the page, and thrust it between the small rollers, which give it the final mangle and hurry it out to the delivery.

The characteristic of the Hoe folding apparatus is that

the movement is rotary throughout: the paper never goes back; its course is entirely an onward one, and the web is not cut until just as it leaves the folders. The result is that the paper supports itself all through the machine, and the tapework is reduced to a minimum. The reels of paper taken by these double machines are enormous. Those for the *Daily Chronicle* are ninety-four and a quarter inches wide; but these are not the widest, for those used on the

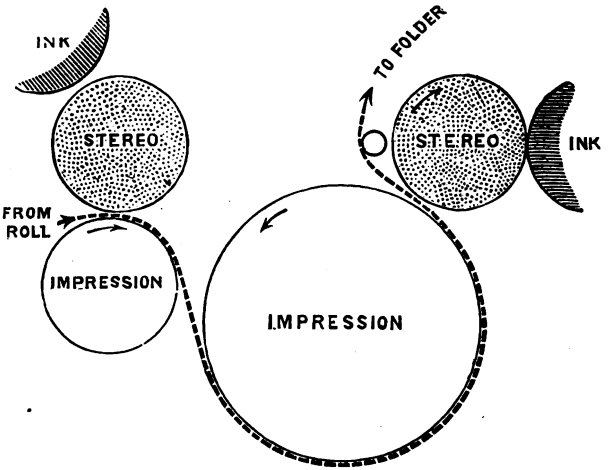


FIG. 4. HOE.

Philadelphia *Ledger*, Mr. Childs's paper, are eight feet wide. Half-rolls can be used if desired; half the press can be used; no paste need be used unless required; the paper can be delivered in separate pages. In fact, there are many possible combinations of this useful contrivance, which, taken at its best, delivering the papers inset, pasted, cut top and bottom, turned out compact as a pamphlet, and, by an additional device much used in America, even folded

and wrappered ready for post, is a veritable triumph of mechanism.

This is the latest of the Hoes, be it understood. The bulk of the machines used in newspaper work are not of this character; but the single rolls, single widths, and double widths now in use in most offices will all eventually be superseded. Hoes, Walters, Marinonis, Prestonians, and Victories divide the London work amongst them. Every paper has its reserve, so that the number of machines is not a satisfactory test of circulation; but taking them altogether, it will be found to be no exaggeration to say that between two and four o'clock every week-day morning 1,000 miles of London newspaper are given to the world by means of the rotary press.

III.

A remarkable and not a pleasant feature of mankind, if we come to consider it, is that of glorifying the inventions of the past and vilifying the inventions of the present! The ancient principle of let well alone, that fine old principle that would have left man even without a stick to till the ground with—for why should he worry himself to save his fingers?—is not one to be proud of, and it is one that man never is proud of unless he has a chance of applying it to those alive around him. He will hold the mirror up to Nature: but he will never himself stand squarely in front of the mirror. And therein he is like the dull printers of whom we now make sport.

For many years, both here and in America, the book printers would have nothing to do with the new machinery. And a dozen years ago it would have been decried as impossible to print an illustrated journal from the reel, just as the printers of 1820 proved to their own satisfaction that woodcuts could only be printed with the venerable platen. 'What!' said they, 'print them in a mangle, with a forme inked with a stick of treacle! Impossible!'

'It was almost the unanimous opinion of the printing trade,' says Mr. De Vinne, 'even as late as 1840, that really fine woodcut presswork must be done on the hand-press, and on hand-made paper.'

Charles Knight was of a different opinion. He was persuaded that it was possible to print woodcuts by machinery; and, encouraged by the Society for the Diffusion of Useful Knowledge, he began in 1832 the *Penny Magazine*, which was the pioneer of modern illustrated journalism.

The machines on which the *Penny Magazine* was printed were the same in principle as that in Nicholson's 1790 patent; and the Wharfedales, Bremners, and other

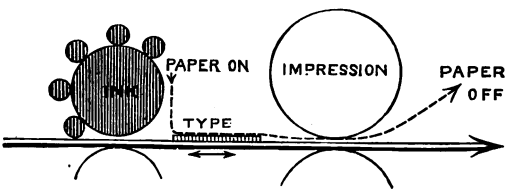


FIG. 5
NICHOLSON.

machines on which is printed most illustrated work to-day only differ from them in detail. The forme, in which the illustration is set, remains flat, it is inked under rollers as it travels, the paper is fed into the machine in separate sheets, and a cylinder running in one direction or in alternate directions presses the paper on the forme as it travels under it and obtains the impression; while in perfecting machines—that is, in machines printing on both sides of the paper—there are two impression cylinders, and the other parts are duplicated.

Admirable as are these machines—and the best of work is done on them—it is evident that for periodicals running long numbers they will soon be replaced by the rotary press. The great difficulty has been to curve the blocks from which the illustrations are printed. To curve a

stereo of type is now easy enough, but to bend an illustration without distortion is a more difficult matter. Mr. Ingram of the *Illustrated London News* has minimized this difficulty in a very ingenious way. In his machines he prints his unillustrated forme on a cylinder of the usual news diameter, but the outer forme—that which prints

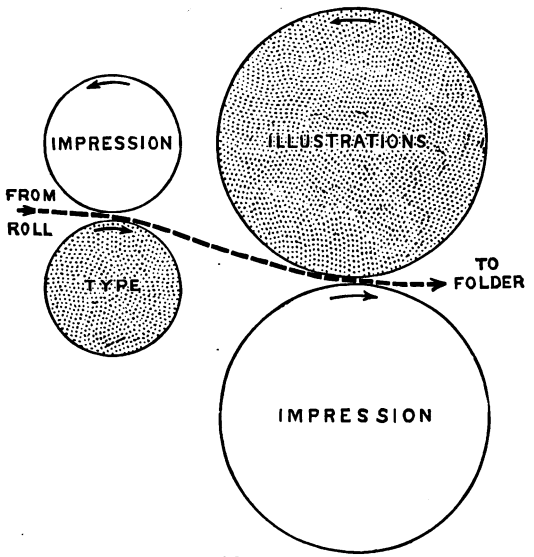


FIG. 6.
INGRAM.

the other side of the paper on which the illustrations come—is of double the diameter of the other. This cylinder has two sets of formes, and travels at half the speed of the first. Two impressions are thus obtained from the first forme before the paper takes the double impression from the second. The curve of the illustrations is consequently very flat; and this idea has been further

carried out in the new Marinoni, such as was introduced into this country to print *The Girl's Own Paper*, and is now, with the Middletons, printing the *Daily Graphic*, wherein the cylinders all carry a double set of plates.

The illustrations are all printed from stereotype or electrotype. They are prepared in many ways. They are drawn on the wood and engraved; or they are drawn on paper and photographed on to the wood and engraved; or they are drawn on paper and transferred to a printing block by means of one of the many processes; or where great fineness of line is required, they are engraved on wood and then reduced by process on to the blocks in the way that has been adopted for some time by *The Century* and other American magazines.

In the old style of wood-engraving the subject was drawn on the wood; in the new it is photographed on to the wood, and the original drawing remains as a guide and check to the engraver. This photographing is managed in several ways, but we will only take two as examples. Something more is required beyond merely making a photograph. The boxwood block consists of many blocks all screwed together, for, owing to the cutting being made on the upright fibre, single blocks large enough are seldom procurable; and if this compound block be made too wet it will become uneven, and spoil. Again, nothing must be put on its surface which will clog the engraving tool or make the cutting more laborious; and again, whatever chemicals are used must not make the wood rotten or friable, for, if so, fineness of line is impossible.

In one method, then, the drawing is placed in front of a camera, a negative is taken of it, and from this a clear thin positive is obtained, also on glass. This is toned and fixed as if it were a transparency, and then soaked in a weak solution of sulphuric acid to loosen the film. A piece of wet albumenized paper is laid on it, and when pressed brings the film off safely, to be transferred to the wood block and left till it is dry enough to be cut into.

One more method will suffice. The block receives a

layer of white colour, which has been mixed with a solution of gelatin and water. A solution of red prussiate of potass and water is mixed with a solution of ferric citrate of ammonia and water, and this mixture is made and brushed over the block in the dark. A negative of the drawing is taken in the usual way, and this is placed over the block, which is then subjected to the action of the light. In less than a quarter of an hour the block is returned to the dark room, and there washed with a wet sponge, when a beautiful blue picture is revealed on it. Had a salt of uranium been used the picture would have been red. Should the image be too dark, a few drops of sulphuric acid soon lightens it up.

The engraver cuts down into the wood, leaving only such parts of it as he wishes to print from. If the drawing is one in line, the lines he leaves are those of the artist, and consequently where the lines cross he has to cut out minute lozenges; but if the drawing is in wash, or if the original be a photograph of a picture or some natural object, he has to work in the manner he thinks best to obtain the effect.

Proof impressions are printed on a hand-press, but in these days the wood is not further printed from. It is used merely as a source of electrotypes. A squeeze in wax or some such substance is taken from it; the mould so produced is dusted on the inside with plumbago, and attached to the zinc pole of an electric cell, of which the other pole is a copper plate, and when the electrical action is set up the transference leads to a fine deposit of copper in every hole and corner of the dusted wax, which deposit is necessarily a facsimile of the engraved portion of the block which yielded the squeeze. The copper electro thus produced is mounted type high, and becomes the block from which the printing is made.

But wood-engraving no longer flourishes as it did. It is an art requiring two artists—the draughtsman and the engraver, the more mechanical of the two having the last, and most important, word. In this it is at a disadvantage, and in another respect it is unfavourably situated, for when good work has to be done engraving is not cheap. No

wonder, therefore, that it is being superseded by the 'processes,' which cost less, and require no middleman.

These processes are nearly all photo-mechanical, and most of them are based on the discovery that a colloid substance such as gelatin, starch, or gum, when mixed with an alkaline chromate, such as bichromate of potass or ammonia, and exposed to the light, becomes insoluble in water. Ordinary gelatin swells in cold water and dissolves in hot. Treat it with bichromate, expose it to the light, and then wash it in cold water. Where the light has fallen, there will be an irremovable film of hardness; and where the light has been stopped from falling, the bichromate will soak out and the gelatin swell. But wash it in warm water. Still the film of hardness will remain, but the rest of the material will simply disappear in solution.

The way in which this discovery can be utilized is easily intelligible. A negative is taken of a drawing, and in it the lights and shades are of course reversed: where the drawing is dark, the negative will be light; where it is light, the negative will be dark. The negative is laid on the prepared gelatin, and exposed to the light, when another reversal takes place, for where the negative allows most light to pass the thicker will be the hardened film beneath. In this way the gelatin slab is split into two layers, a soft unaltered one and a hardened one, with the elevations extending downwards away from the negative, just as the ice on a sheet of water is thickest where the cold is greatest; and the gelatin has only to be turned upside down and washed to have its soft layer cleared away, and leave a relief which can be printed from to obtain such effects as in the collotype, where the photographic origin of the print is unmistakable.

The turning upside down is not necessary where there are no half tints, or where the half tint is obtained by a 'texture.' In 1841, when Joseph Dixon wished to copy bank notes in America, he mixed gum arabic with bichromate of potass on a lithographic stone, and exposed the sensitive surface to the action of light through the banknote he wished to copy. Where there was ink on the note, the gum remained unaltered; where the light passed

through the paper, the hardening took place; and all Dixon had to do was to wash away the unaltered gum and ink the stone and proceed as in lithography.

With regard to this alteration of bichromatized gelatin, an important discovery was made by Paul Pretsch. He found that the surface of the less-exposed parts was covered with a multitude of tiny crape-like markings or folds, due to the strains that were set up in the mass resulting in interlacing folds and fissures. By utilizing these markings he secured his half tints for letterpress printing. After exposing and soaking he had a film with high lights raised and smooth, with middle lights raised and grained, and with blacks deepened and smooth. Of this he took a cast, and then by a double electrotyping he got his printing surface.

Half tints have been the difficulty of all process inventors. For fast machine printing it is indispensable that they should be obtained in some way from a surface which, like type, is all on a level. Satisfactory results can only be had from blocks in which the r dulations of light and shade depend on different thicknesses of line. A block dependent for its 'greys' on different degrees of depression would soon yield nothing but a smudge. What is wanted is a 'discriminating tint' giving thickness in the blacks and fineness in the half-lights.

One process arrives at the tint by a combination. A transparent plate is hatched or stippled in parallel lines, or rather a screen so hatched is photographed on to the plate; a transparent positive is made of the drawing; the two plates are then placed together, and from them a negative is photographed in the ordinary way; but in the camera the lined negative undergoes a certain amount of shifting, in order to cross-hatch or break the lines and give the discriminating grain. This shifting is the secret of the process, and the only thing for which novelty is claimed in the patent. In fact, the notion was not new. But if we diverge into patents our task will be endless. Let it be said once for all that most of them are worthless, and that the only protection is in some trivial secret of manipulation.

There are other grain processes besides this one. There is one in which a grained glass is used, which has given most beautiful results even for fast newspaper printing. There is another in which glass powdered to flour is used; there is another in which dust is thrown up in front of the negative while it is in the camera; and there ought to be one in which the air-brush is used, if only some one would think it worth while to do so.

We may divide the ordinary newspaper printing processes into two groups—one being photo-relief, the other zinc-etching.

In photo-relief the sensitized gelatin is hardened by the light, as we have said, so that the lines left in the shaded soft compound can be washed out, and the depressions accentuated by the swelling of the mass beneath the hard film on either side. Of the slab thus washed a wax cast is taken; the wax cast gives a plaster-of-paris mould; and the mould gives the cast in stereo metal.

In the zinc-etching systems the gelatin is spread on the zinc, and when the negative is removed the slab is washed and inked; it is then cleaned to clear away the ink that is not filling the depressions; and then it is placed in an acid bath to be etched. The hardened gelatin is bitten away on each side of the inked lines, and would be bitten away beneath them were not steps taken to prevent it. Powdered rosin is dusted over the plate so as to rest on the inked ridges and roll down their flanks and protect them, but only so much rosin is used as will remain on the flanks without reaching the valley between. Another etching is then given, and in this way the ink is borne on sloping ridges with V-shaped troughs, the troughs being of course very shallow, and sometimes being made more shallow by the ridges receiving a final planing. It is often noticed by artists that when a drawing is reduced by process the thickness of the lines is not reduced in proportion to the reduction of the drawing, and it is almost as frequently answered that the statement is absurd. But it is true nevertheless, for the lines in the process-block can be thickened in three ways—either by the final planing or by the dusting on of the rosin or by the coarse grain of the zinc.

Drawings for these photo-mechanical processes have therefore to be made with specially fine lines, or they can be photographed on to wood first, cut finely, and then reduced on to the gelatin. But all drawings will not photograph satisfactorily, for care must be exercised in the choice of pigments. Yellows will turn darker in the photograph and blues will turn lighter; consequently the most fitting colours are the pure blacks and greys. Many draughtsmen for process mix their colours like Reynolds did—with brains and prejudice—but in one quarter, at any rate, the secret seems to be that there is no black like lampblack, except it be lampblack with a little gamboge to give it depth.

'Process' is, however, a wide term. Some of the processes used by our newspapers are not even photo-mechanical, the effects being produced by an eidograph or pantagraph scratching in wax on zinc to be etched, or in wax or plaster-of-paris to be electrotyped or stereotyped from. Some are ordinary photo-zincographs drawn on prepared paper and transferred full-size to the metal. But such rough-and-ready methods are evidently doomed. Every month the photo-mechanical processes are improved; and if they could only be got to give a deeper, sharper plate, so as to be workable by the ordinary printer (who is always so free with ink in the wrong place), it would be time to write the epitaph of the last of the wood-engravers, who may possibly be said to have died of bichromatized colloids.

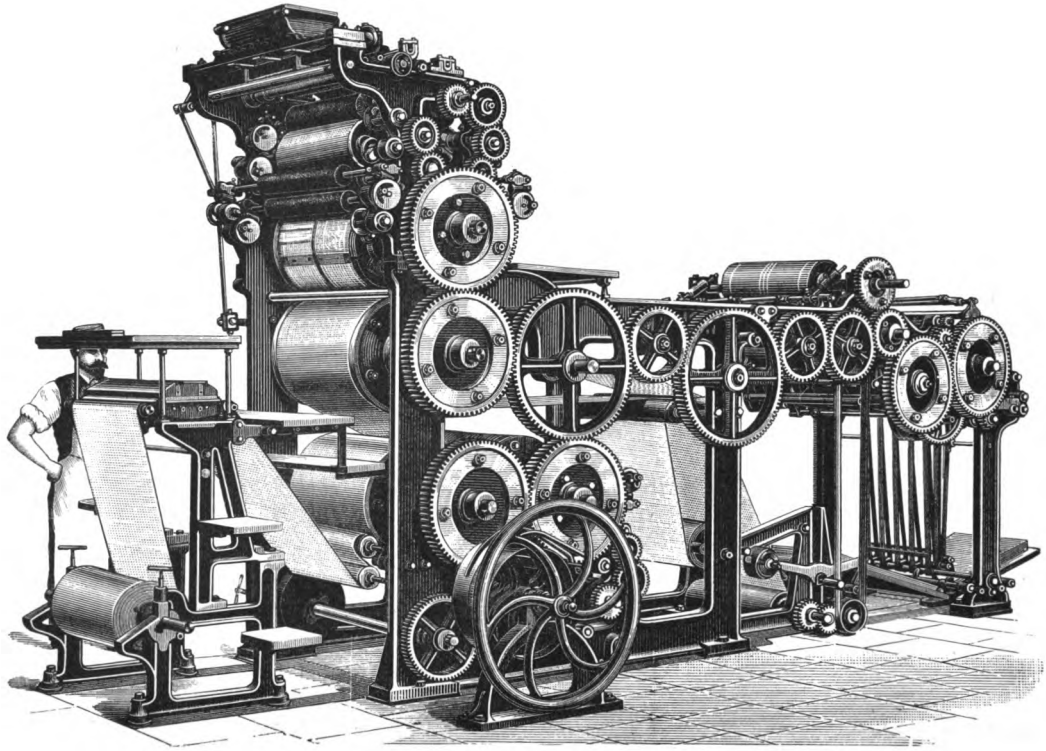
Let us return to our main road with the electrotype from the wood, or the block from the process. The block is then set with the type, and a careful cast is taken from the forme as in ordinary newswork, or curved electros of the cuts are fitted in.

But illustrated work differs from ordinary newswork in one important particular. In a mass of type of the same size the pressure is even, but where there are blocks with much black in them or much open work, the resistance is uneven, and the pressure consequently varies. The black blocks resist more than type, and open blocks hardly resist at all; and thus cuts with much contrast of light and shade require much more pressure in some parts than in others,

and to print a cut properly the pressure must be in proportion to the resistance.

The way in which this result is obtained is called overlaying. Thomas Bewick, of Newcastle, the father of modern wood-engraving, is said to have introduced overlays; but this cannot be true, for there are marks of unequal pressure in several sixteenth-century prints. Bewick, too, is said to have been the first to lower his blocks a shade where he wanted a delicate tint; but the dodge is at least as old as Holbein's 'Dance of Death.' He also is said to have been the first to cut on the columnar fibre of the wood; but that practice was recommended in Papillon's book when Bewick was six years old. However, he may have been the first to use all three contrivances together; and as to the overlaying, he certainly seems to have independently invented it or revived it after a long interval.

The practice is somewhat of an art or mystery, but its principle is clear. The printer cannot decrease the ordinary pressure, but where blackness is wanted the pressure can be increased by thickening the cylinder, and the cylinder is thickened just at the spot required by pasting pieces of paper on to it. These pieces of paper have to be of a peculiar shape, and the shape depends on the subject. Three or four impressions of the cut are taken on thinnish paper. These impressions are not like artists' proofs, in which the ink is modulated, but they are hard, crude pulls, showing what the cut would look like if left to itself; and the printer's object is to arrange his overlays so as to make the impression worked off the machine look as much like the artist's proof as he can manage. With a pair of scissors he snips out of one of his flat pulls all the light shading and fine work. He then snips away from another pull everything but the deep blacks. He then snips another pull so as to leave the blacks and the half tints. And with another he may leave a little more of the shading. He may even make six overlays, or—and it is better if he can so manage it—he may do with three. He then pastes these together one over the other so as to make the thinnest possible pad on the cylinder, and when they are dry he takes a proof impression,



THE MARINONI ROTARY FOR ILLUSTRATED WORK.

and trims the pad till he has it correct, giving dark where dark should be, light where light should be, and every intermediate tint, but without clogging a line in the dark or losing a single dot in the lightest work of the original. By this slight patch on the cylinder he will probably have attained at the point of greatest resistance a pressure of a thousand pounds on the square inch, whereas in the open work of the cut the pressure will be no more than that on the body of the letterpress.

In the past it was customary to work entirely with soft packing—that is to say, with a thick blanket or cloth between the impression cylinder and the paper, so as to equalize the printing and allow for irregularities in the height of the type. With 'soft packing' the overlays were often very numerous; but nowadays we have changed all that. Our first-class illustrated magazines are printed by the 'hard packing' system, in which the impression is given from an almost unyielding surface. In another point we have improved: we calender the paper and print on it when it is dry. In many of the news machines, as we have seen, the paper is still damped, chiefly because it is so poor and common, but in illustrated rotary work the paper is printed on as it comes from the mill.

In the new Marinoni we have a machine printing with hard packing on dry paper at the rate of 7,000 copies an hour. The cylinders, each of double size, are arranged in the shape of an L, the two impression cylinders in the middle, with a type cylinder on the top and a type cylinder alongside the lower impression one. The paper passes through a smoother, and enters at the very bottom of the machine; it passes upwards as it takes its first type; runs outwards and upwards round the upper impression cylinder; and after receiving its second printing drops down into the folders. There are no tapes, but there is a gathering drum with grippers, which takes four sheets at a time. And before being cut the web passes through some six or seven feet of space, so as to have just the fraction of a moment to dry. One peculiarity of the machine is the set-off arrangement, which consists of a full width web of paper running off one spindle on to another round

the outer forme cylinder underneath the web which is being printed.

As with the other rotaries, the saving of labour is enormous. Work which with a cylinder machine would require twenty men can by it be done with three. When new it can turn out 2,600 copies per hour per man, but like all French machinery it seems to be too lightly built to last,

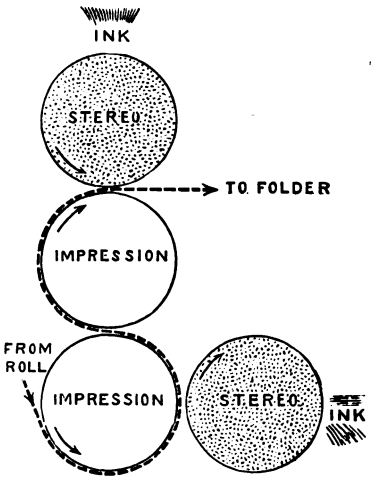


FIG 7
MARINONI

and an opening is thus presented for English makers to excel it not only in output but in solidity.

Forty years ago the Lightning, as we have seen, yielded 420 copies per man of an ordinary-unillustrated sheet. Now our Walters turn out occasionally-illustrated sheets at the rate of 3,140 copies per man, and our Quadruple Hoes have brought the average over 5,000.

A successful newspaper is a profitable property, but the proprietor must be a man of means. The outlay is a serious

matter. Newspaper partnerships do not issue detailed income and expenditure sheets, so that the figures are not easily obtainable, and those given in confidence cannot be published here. But some idea of the running cost of a first-class newspaper is available from the other side of the Atlantic. The *New York World*, which has the largest circulation in America, says that it spends £133,500 a year on paper in the reel, £63,200 a year in type-setting, and once every year has a new outfit of type, costing £2,780. Add to this £22,000 a year for telegraphic news, and then add the remuneration of the literary staff and other salaries and wages, besides the charges for distribution; and the total will look as though it could never be recouped out of the advertisements and sale. But it is, though the percentage of profit on the cost of manufacture may be a fraction with a two-figure denominator. And consequently the price per copy has dropped much, and will drop more.

There are two main causes for the cheapness of our newspapers. Thanks to new materials, new machinery, and no duty, the paper costs but a quarter what it used to do; and though rotary presses at £7,000 apiece require a somewhat alarming sinking of capital, yet so great is the saving of labour that with higher individual wages the mere printing costs not a tenth of what it did in the days of the Lightning, and not a hundredth of what it did at the time of Nicholson's patent a hundred years ago.

THE END.

RICHARD CLAY AND SONS, LIMITED
LONDON AND BUNGAY.